

Review of Networking Basics



Outline

1. Network & Internet Architecture
2. Protocol Layers (Application, Transport, Network and routing, Data Link, Physical)
3. Network Application
4. Network Security
5. Network Management

1. Network & Internet Architecture

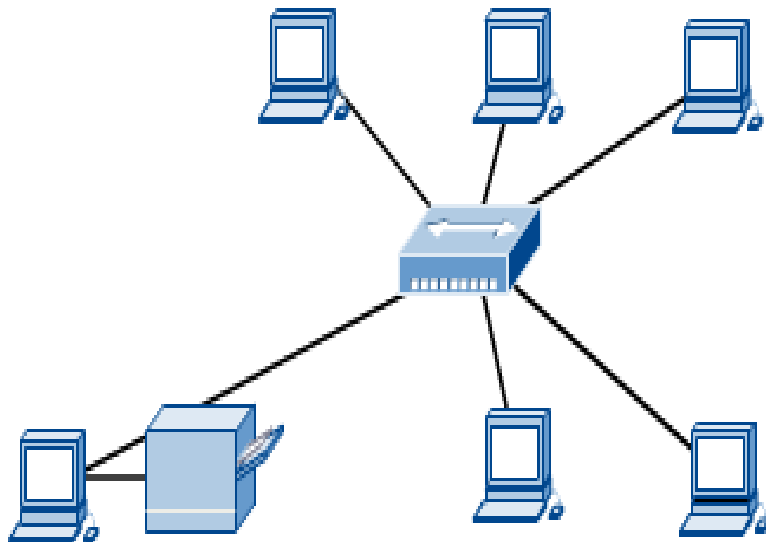
Sub-outline

- Network & Internet Architecture
- Circuit Switching vs. Packet Switching
- Connectionless and Connection-Oriented Services
- Virtual Circuits
- Network Taxonomy
- Protocol Stacks

Network Architecture

Network :

- Computers connected together to communicate among themselves
- Computer network connects two or more autonomous computers
- The computers can be geographically located anywhere.





Why Network?

Resource Sharing

-  Hardware (computing resources, disks, printers)
-  Software (file, folder, application software)

Information Sharing

-  Easy accessibility from anywhere (files, databases)
-  Search Capability (WWW)

Communication

-  Email
-  Message broadcast

Remote computing

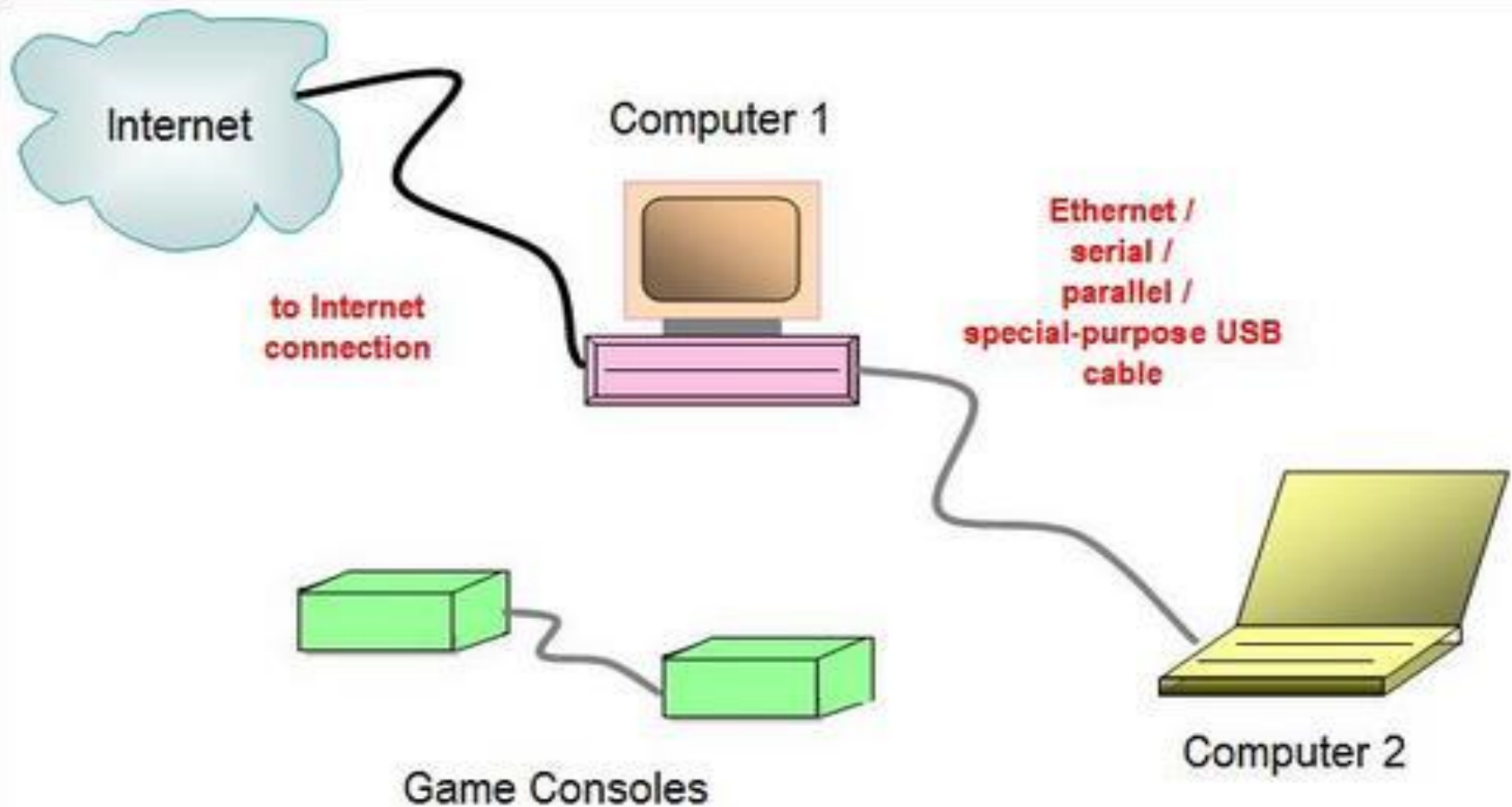
Distributed processing (GRID Computing)

How many kinds of Networks?

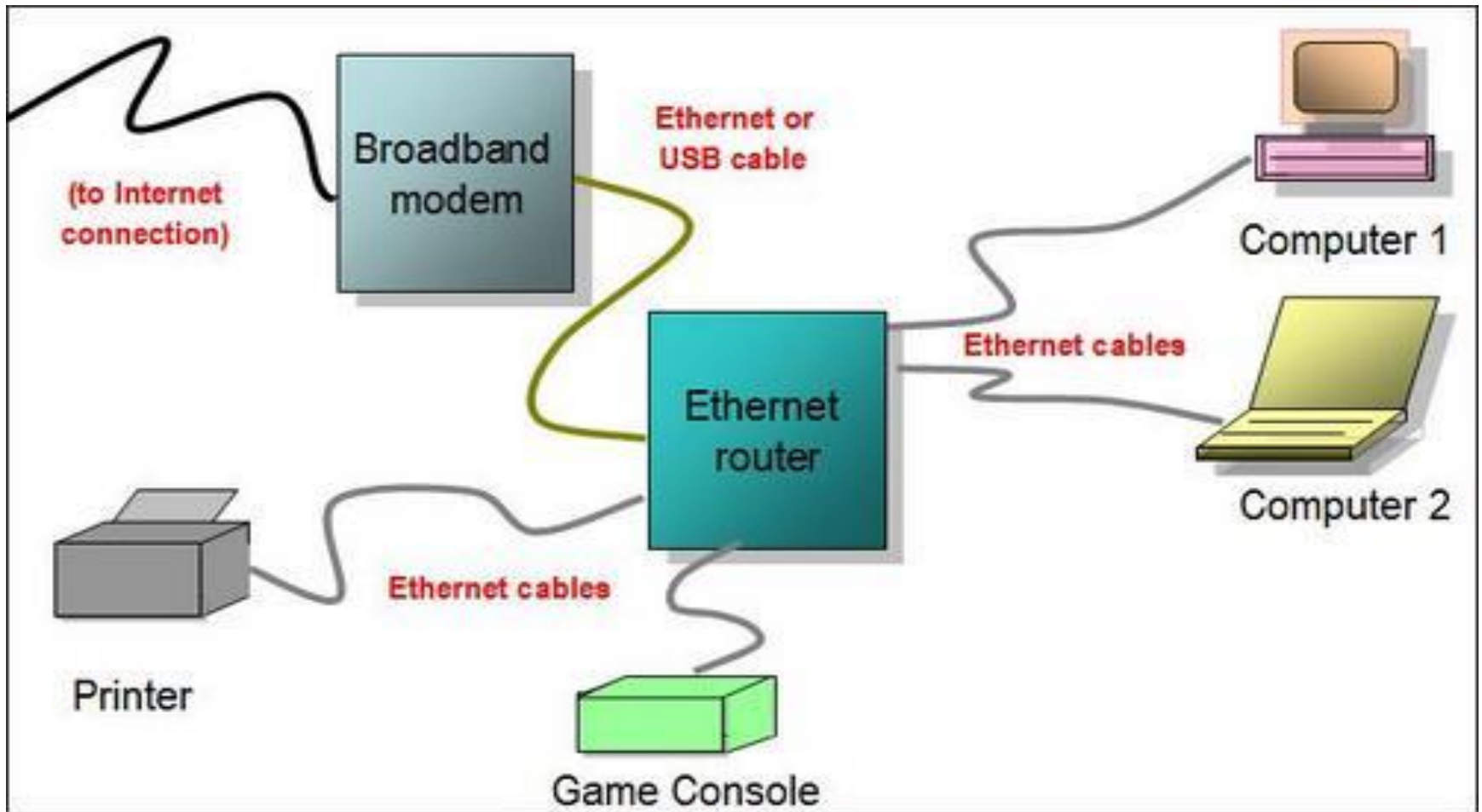
Depending on one's perspective, we can classify networks in different ways

- Based on **transmission media**: Wired (UTP, coaxial cables, fiber-optic cables) and Wireless
- Based on **network size**: LAN and WAN (and MAN)
- Based on **management method**: Peer-to-peer and Client/Server
- Based on **topology** (connectivity): Bus, Star, Ring, Mesh ...
:
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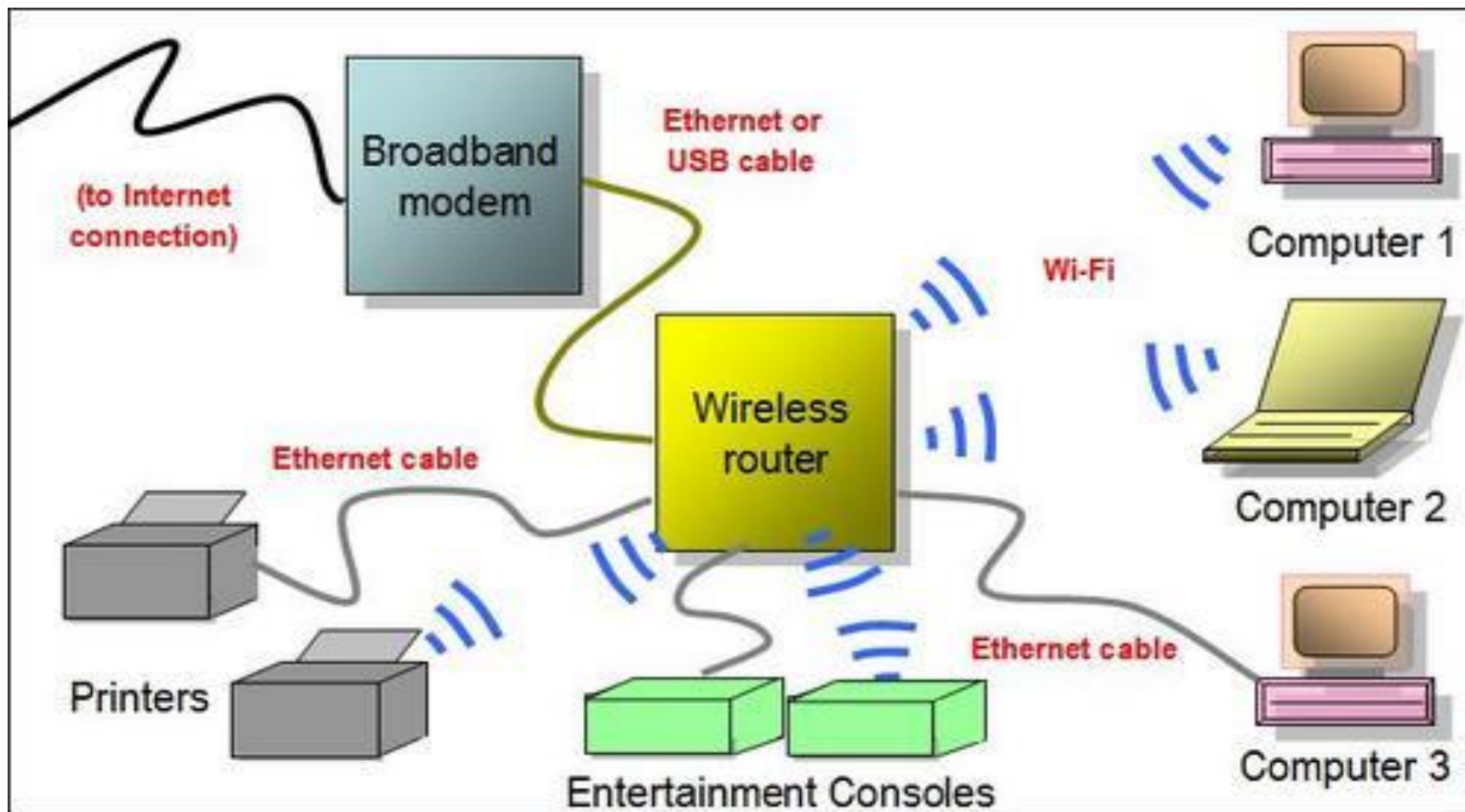
Network Classification by Media-Direct Connect



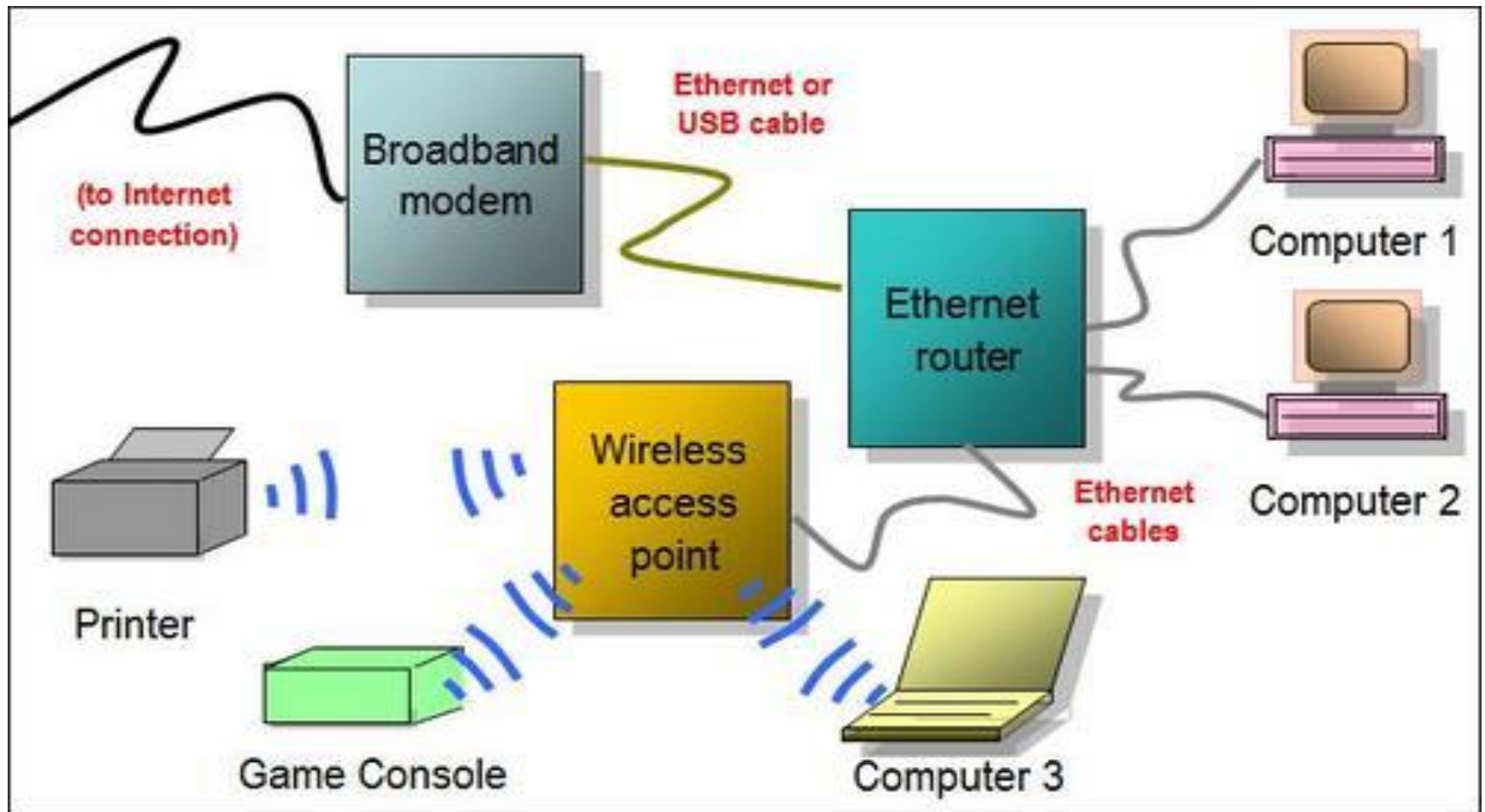
Wired Network



Wireless Network



Hybrid Network



Network Classification by Size

- ~ Computer network technology can be classified by the distance the network technology is designed to span
- ~ There are three types of networking :

- Local Area Network (LAN)
- Metropolitan Area Network (MAN)
- Wide Area Network (WAN)



LAN, MAN & WAN

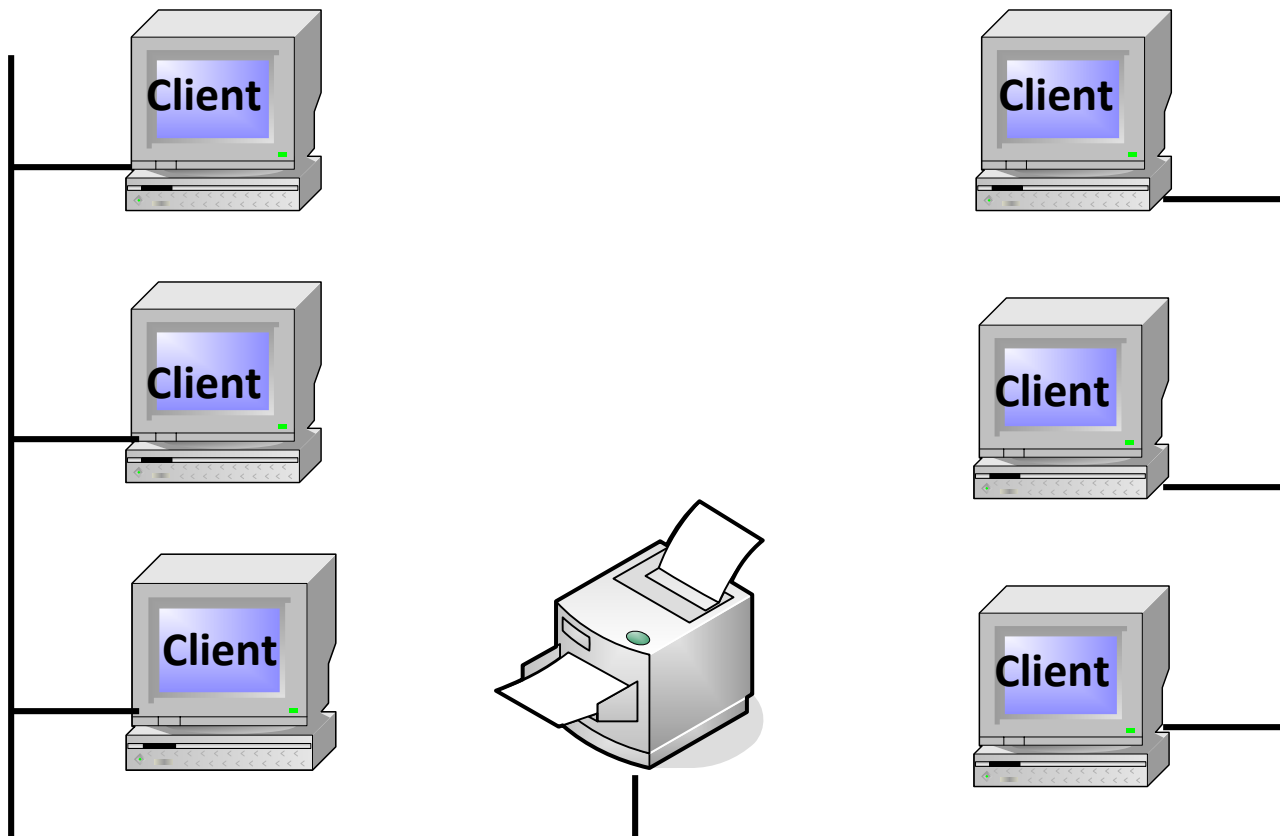
- ❏ Network in small geographical Area (Room, Building or a Campus) is called **LAN (Local Area Network)**
- ❏ Network in a City is called **MAN (Metropolitan Area Network)**
- ❏ Network spread geographically (Country or across Globe) is called **WAN (Wide Area Network)**

Network Classification by Size

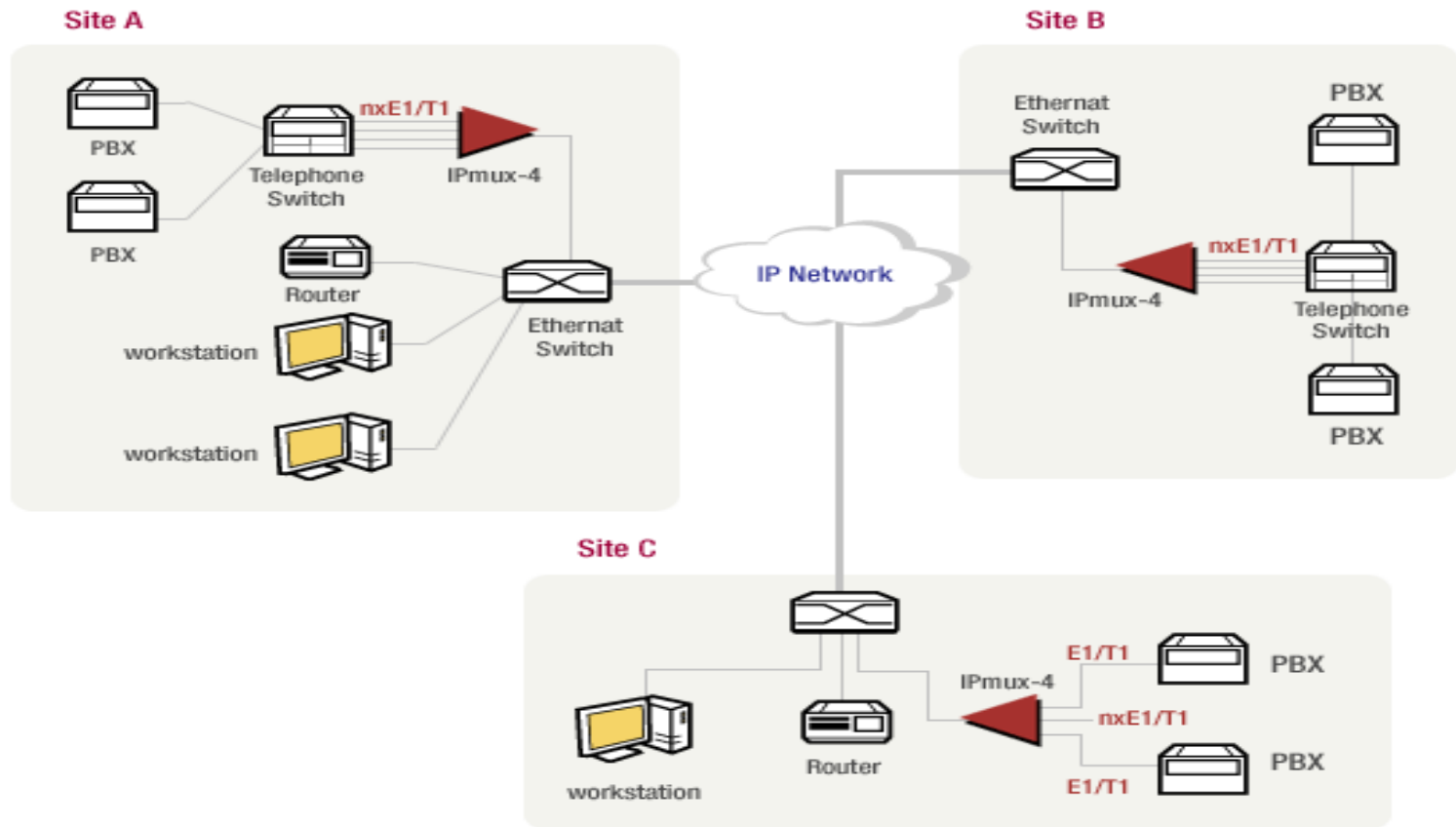
Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Classification of interconnected processors by scale

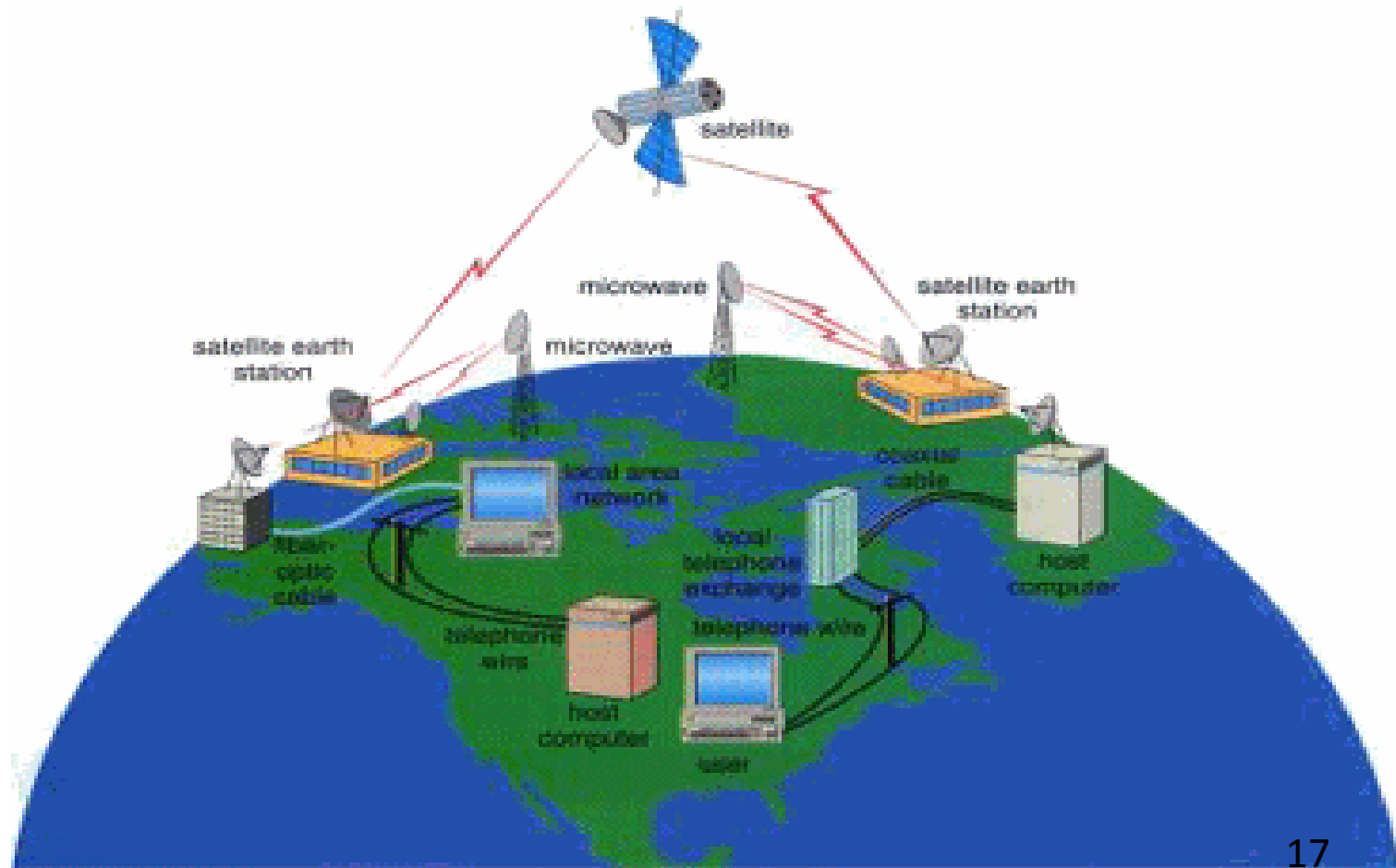
Local Area Network (LAN)



Metropolitan Area Network (MAN)



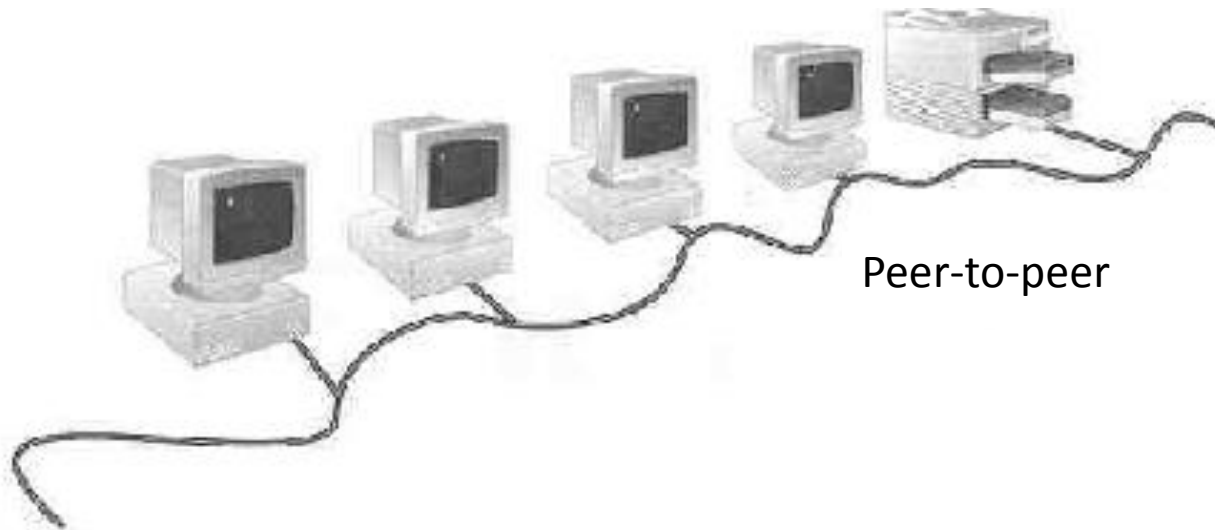
Wide Area Network (WAN)



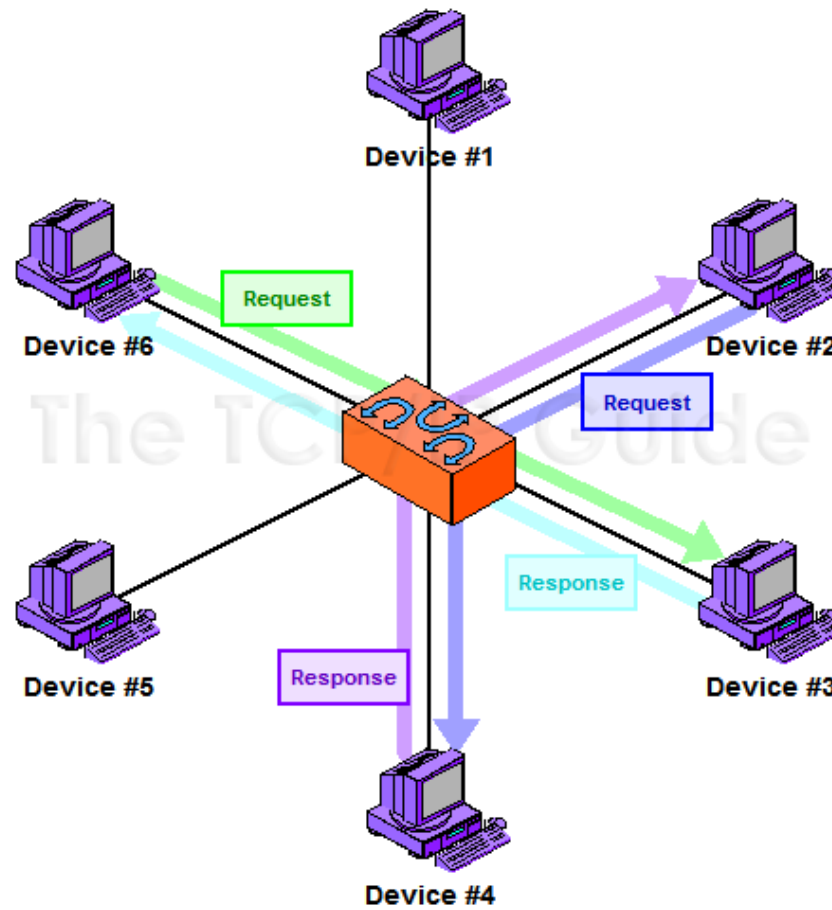
Network Classification by Management Method

Peer-to-Peer Networks

- Peer-to-peer network is also called **workgroup**
- **No hierarchy** among computers $\Rightarrow$ all are equal
- **No administrator** responsible for the network



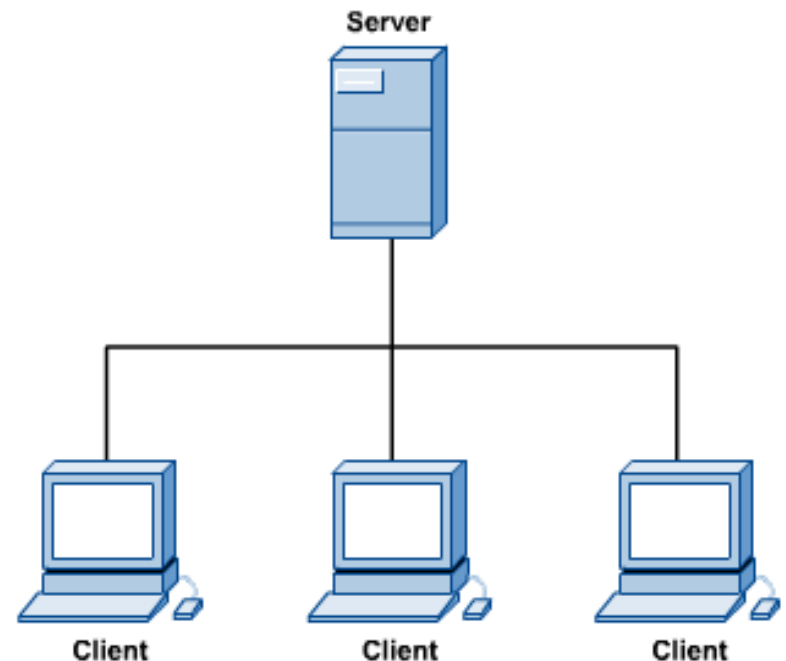
Peer-to peer network



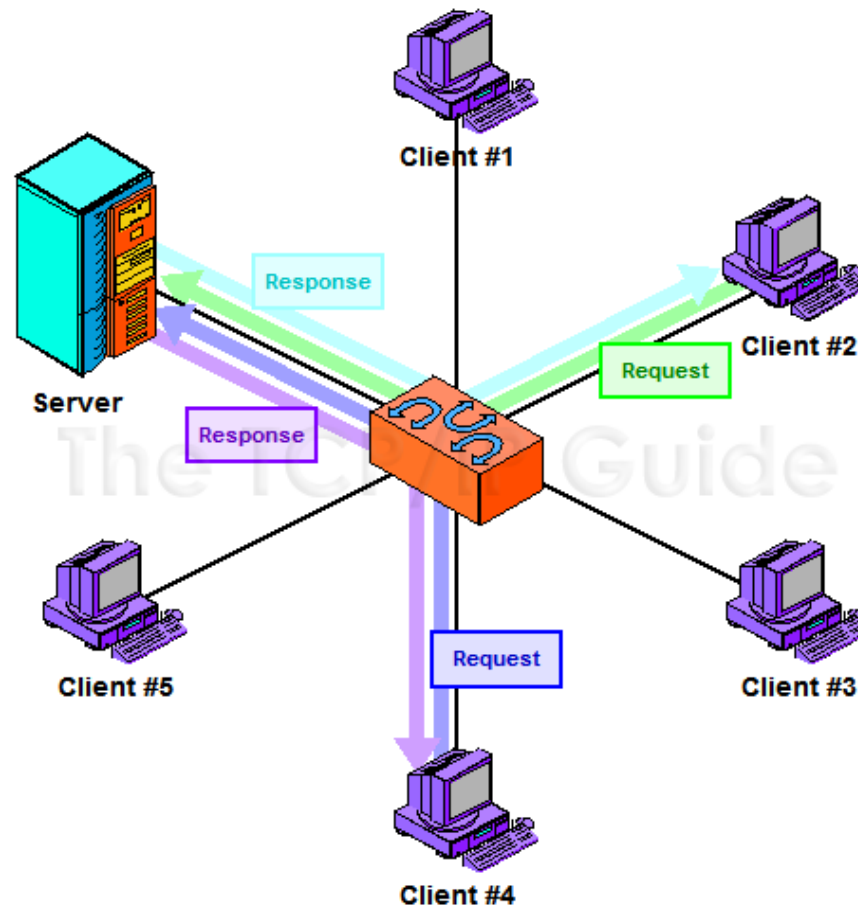
Clients and Servers

network services are located in a dedicated computer (Server) whose only function is to **respond to the requests of clients**.

The server contains the file, print, application, security, and other services in a central computer that is continuously available to respond to client requests.



Client/Server Networking



Network Topology

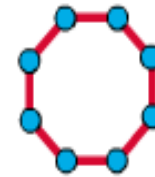
 **Topology:**
connection
computers
network

The physical
among
within a
network

 describes the layout of the
wire and devices as well as
the paths used by data
transmissions.



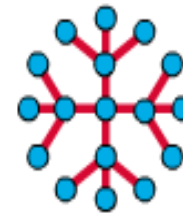
Bus Topology



Ring Topology



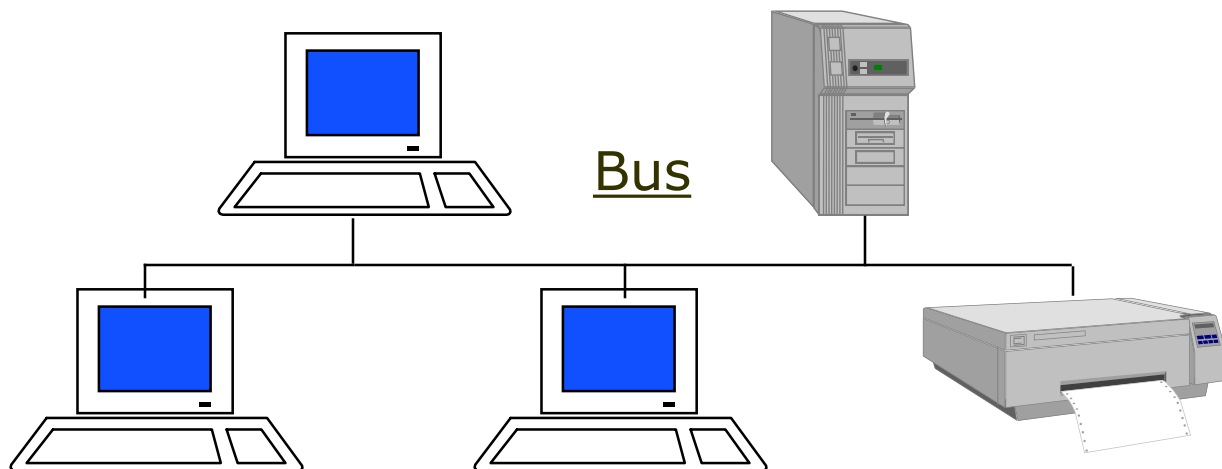
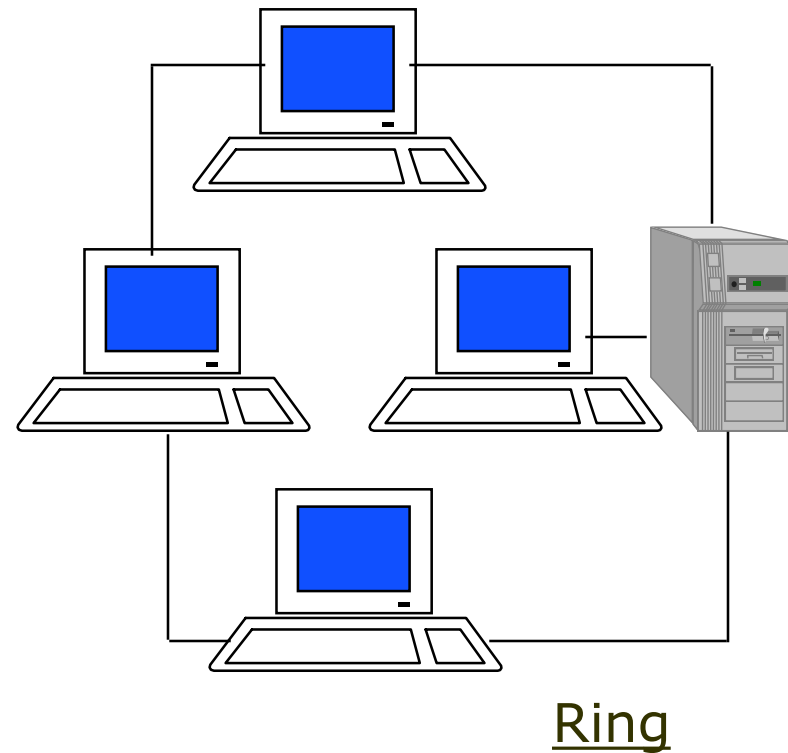
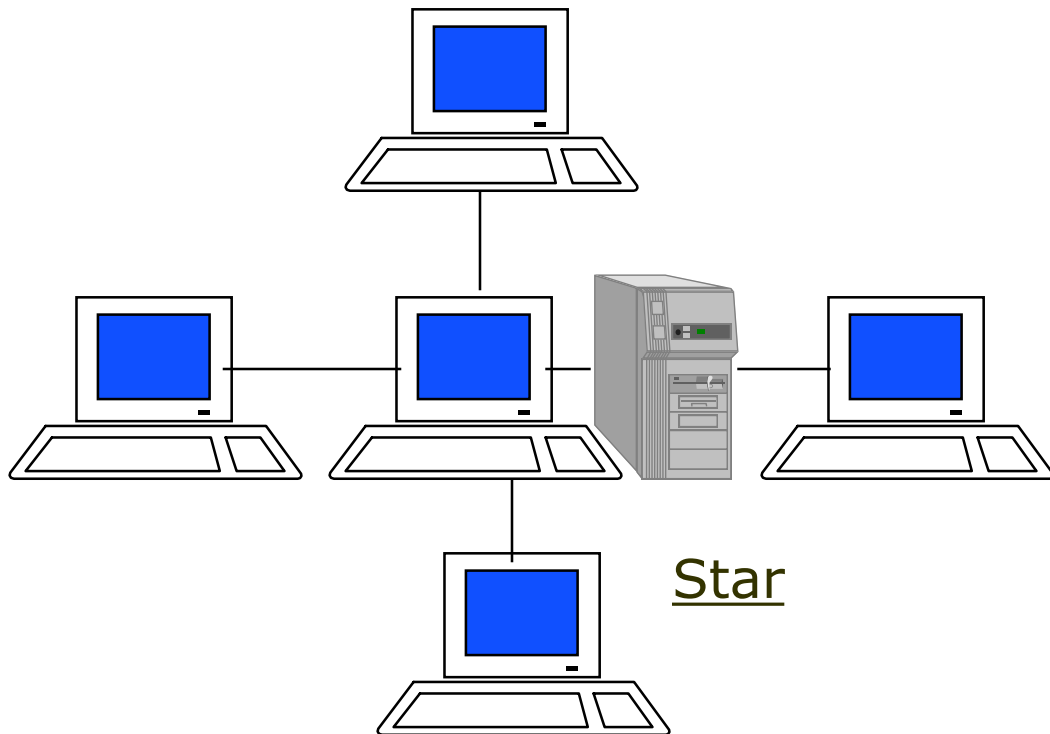
Star Topology



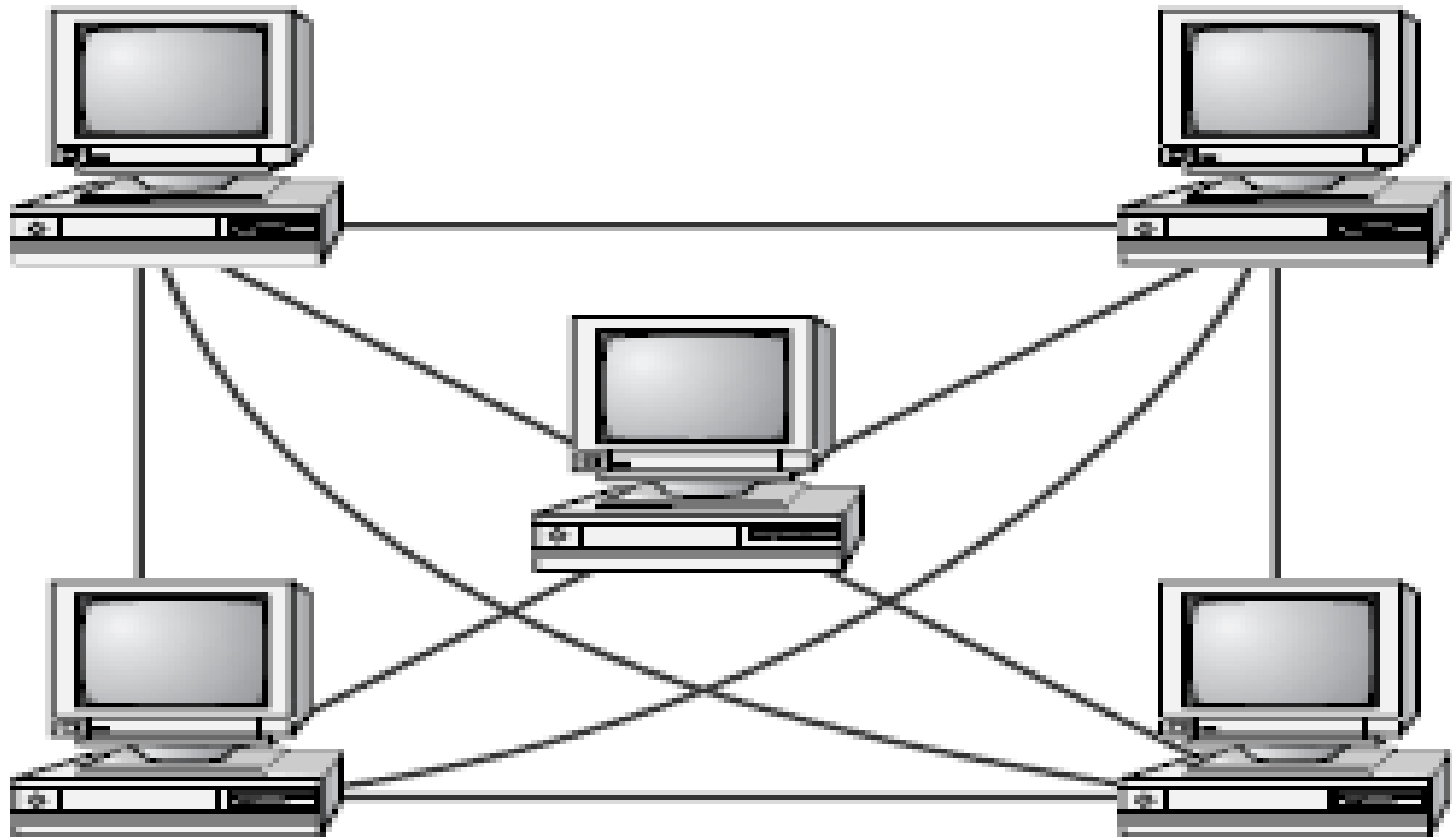
Extended Star
Topology



Mesh
Topology

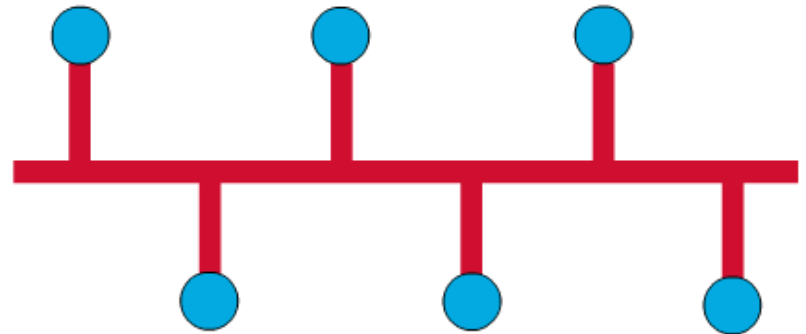


Mesh Topology



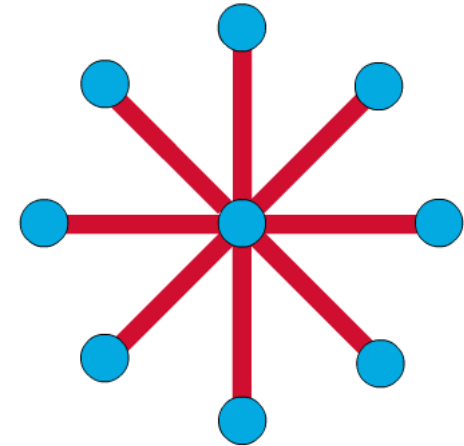
Bus Topology

 referred to as a linear bus, all the devices on a bus topology are connected by **one single cable**.



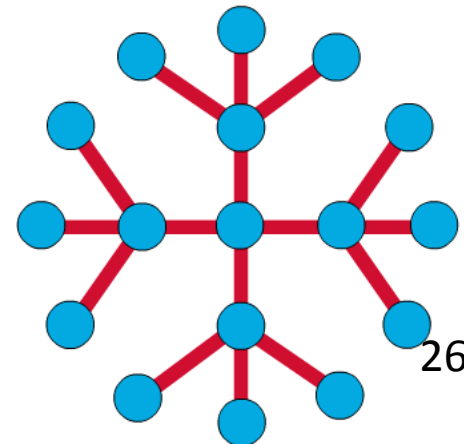
Star & Tree Topology

resembles spokes in a bicycle wheel



Used in Ethernet LANs

the extended star topology also called tree topology



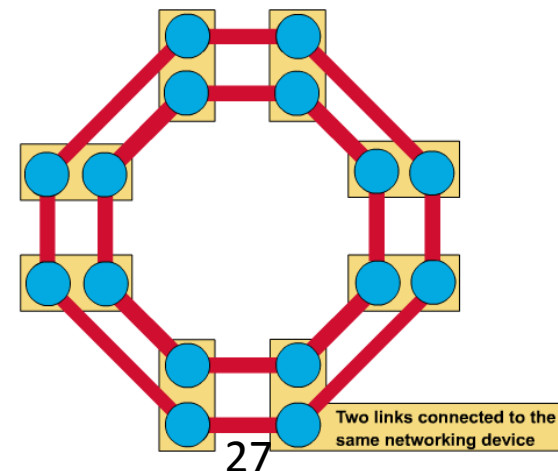
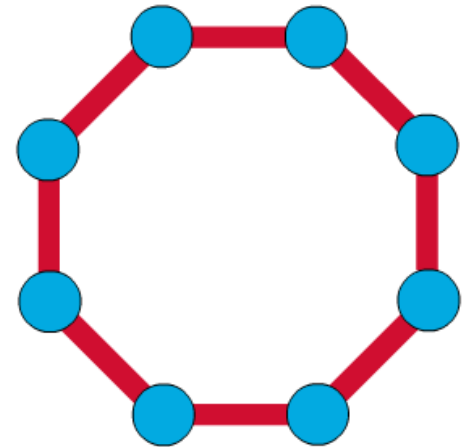
Ring Topology

❏ If a node wants to transmit data, it adds the data as well as the destination address to the frame.

❏ The frame then continues around the ring until it finds the destination node, which takes the data out of the frame.

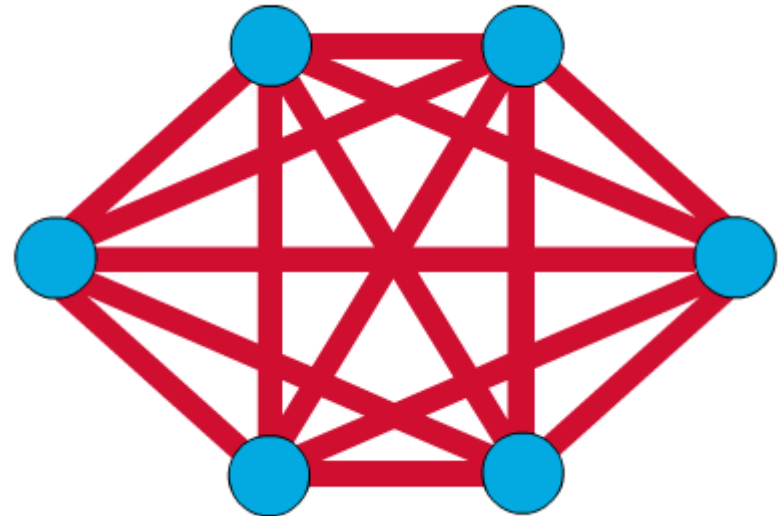
❏ **Single ring** – All the devices on the network share a **single cable**

❏ **Dual ring** – The dual ring topology allows data to be sent in **both directions**



Mesh Topology

- connects all devices (nodes) to each other for redundancy and fault tolerance.
- Implementing the mesh topology is expensive and difficult.



Advantages and Disadvantages of Network Topologies

Topology	Advantages	Disadvantages
Bus	Cheap. Easy to install.	Difficult to reconfigure. Break in bus disables entire network.
Star	Cheap. Easy to install. Easy to reconfigure. Fault tolerant.	More expensive than bus.
Ring	Efficient. Easy to install.	Reconfiguration difficult. Very expensive.
Mesh	Simplest. Most fault tolerant.	Reconfiguration extremely difficult. Extremely expensive. Very complex.

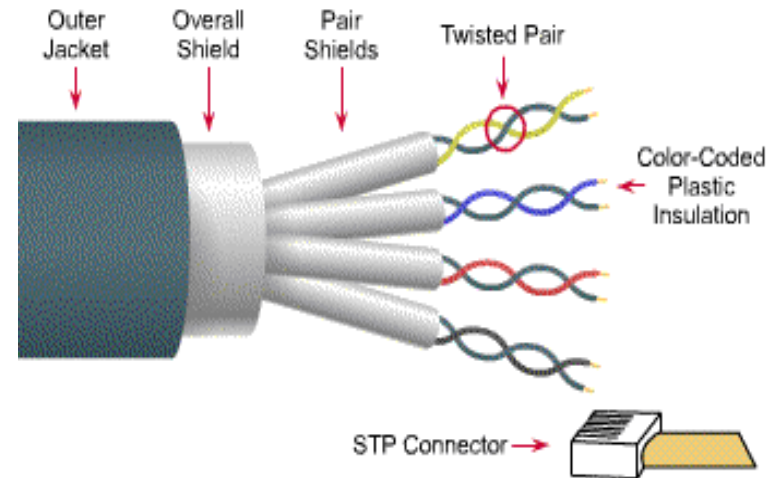


Network Components

-  **Physical Media**
-  **Interconnecting Devices**
-  **Computers**
-  **Networking Software**
-  **Applications**

Networking Media

 can be defined simply as the means by which **signals (data)** are sent from one **computer** to another (either by cable or wireless means).



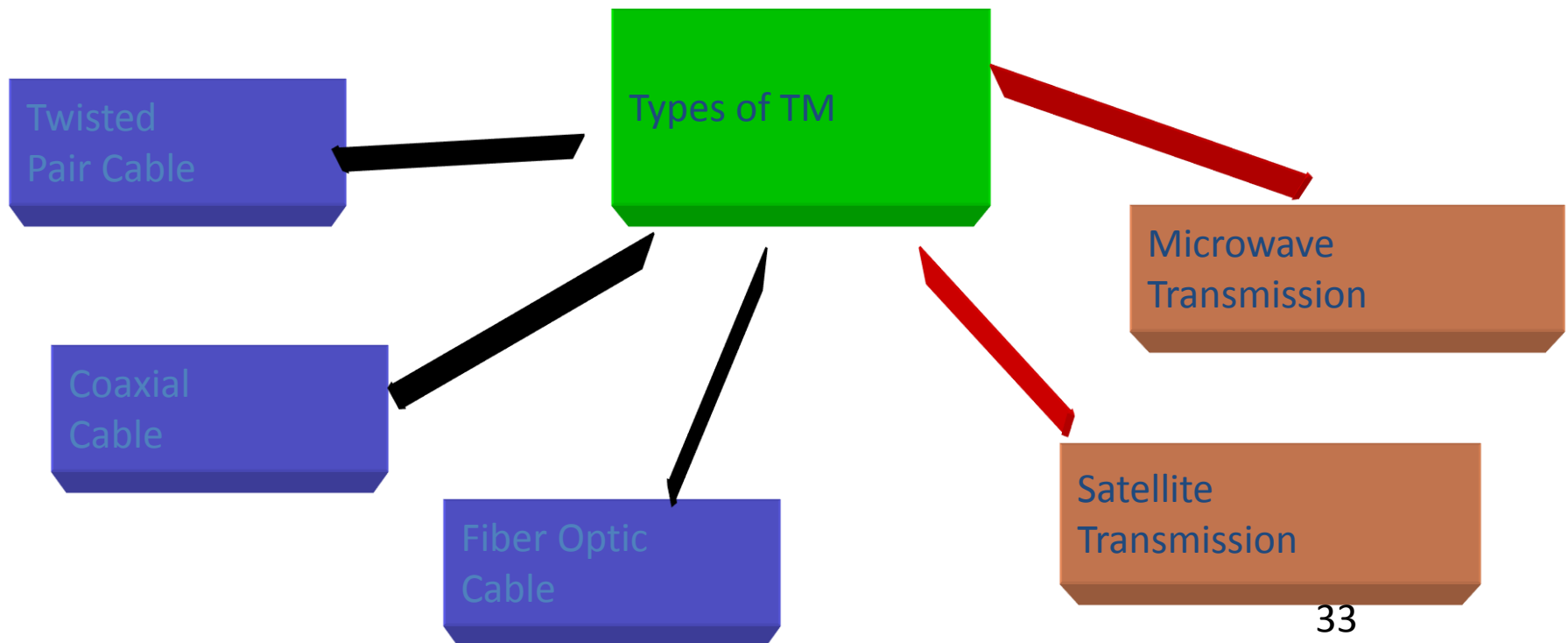
- Speed and throughput: 10-100 Mbps
- Cost per node: Moderately expensive
- Media and connector size: Medium to Large
- Maximum cable length: 100m (short)

Transmission Media

- **Two main categories:**
 - **Guided** — wires, cables
 - **Unguided** — wireless transmission, e.g. radio, microwave, infrared, sound,...
- **We will concentrate on guided media here:**
 - **Twisted-Pair cables:**
 - **Unshielded Twisted-Pair (UTP) cables**
 - **Shielded Twisted-Pair (STP) cables**
 - **Coaxial cables**
 - **Fiber-optic cables**

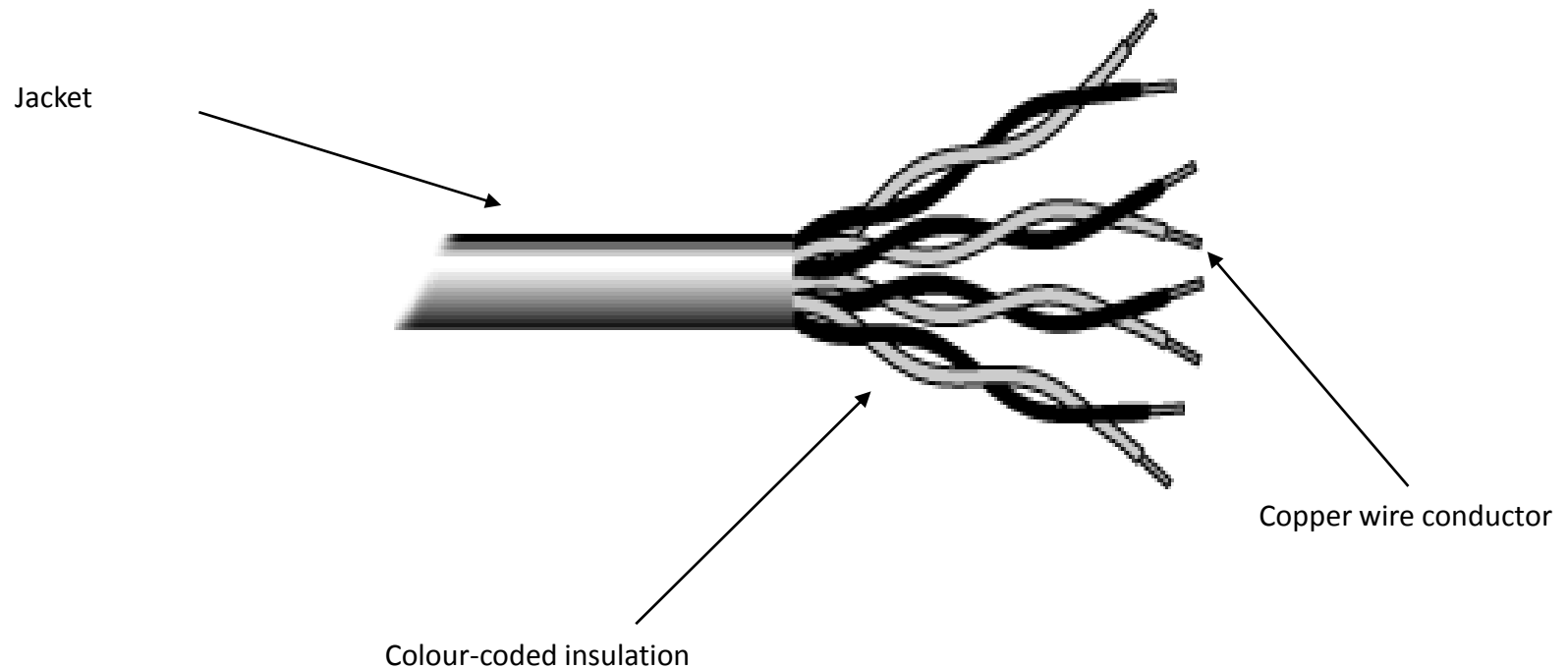
TRANSMISSION MEDIA

Transmission Media : The physical medium used for transmission.



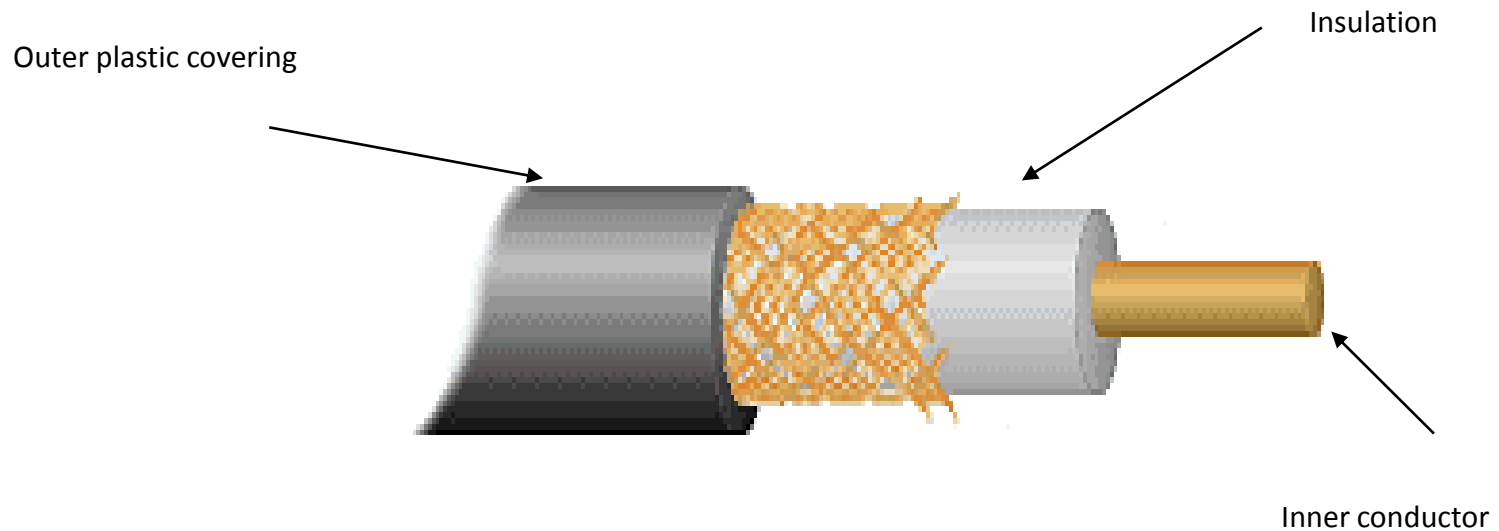
TRANSMISSION MEDIA

Twisted Pair Cable



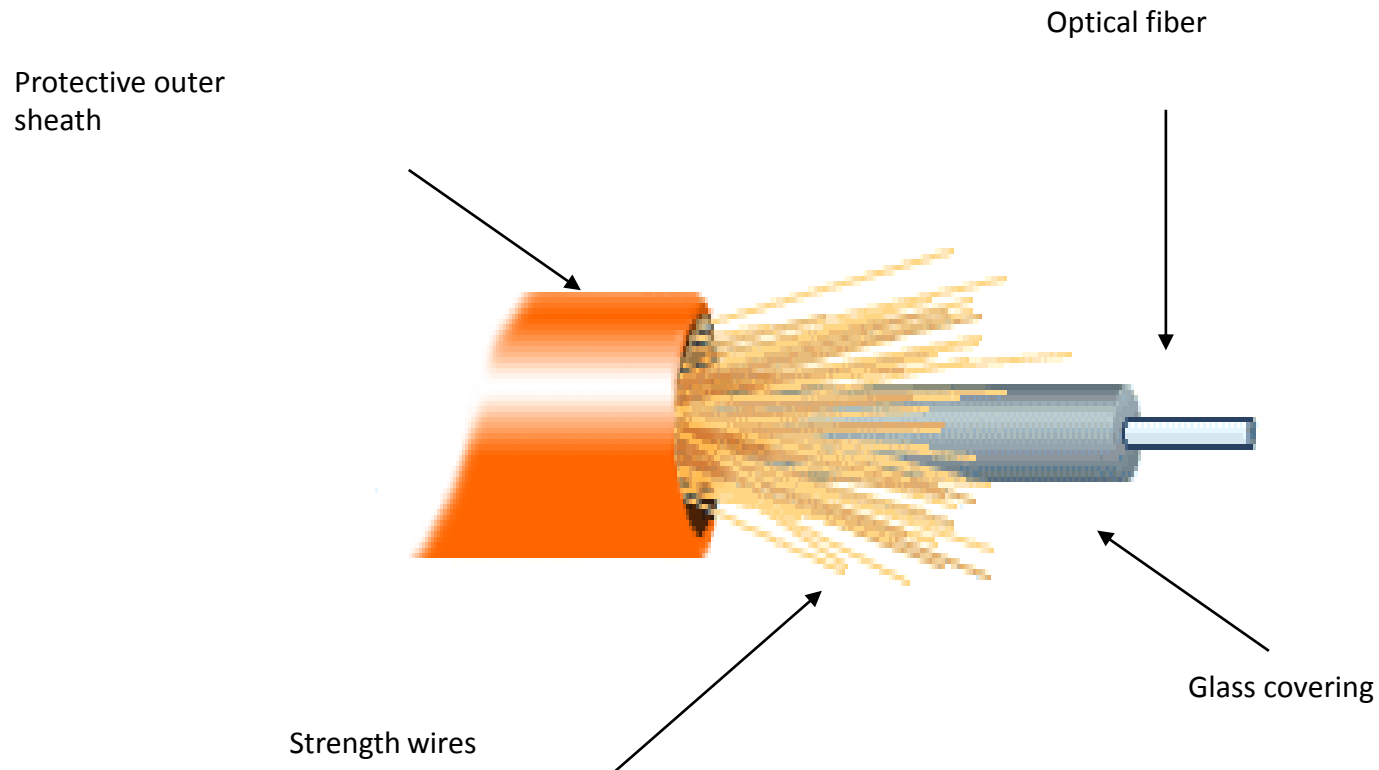
TRANSMISSION MEDIA

Coaxial Cable

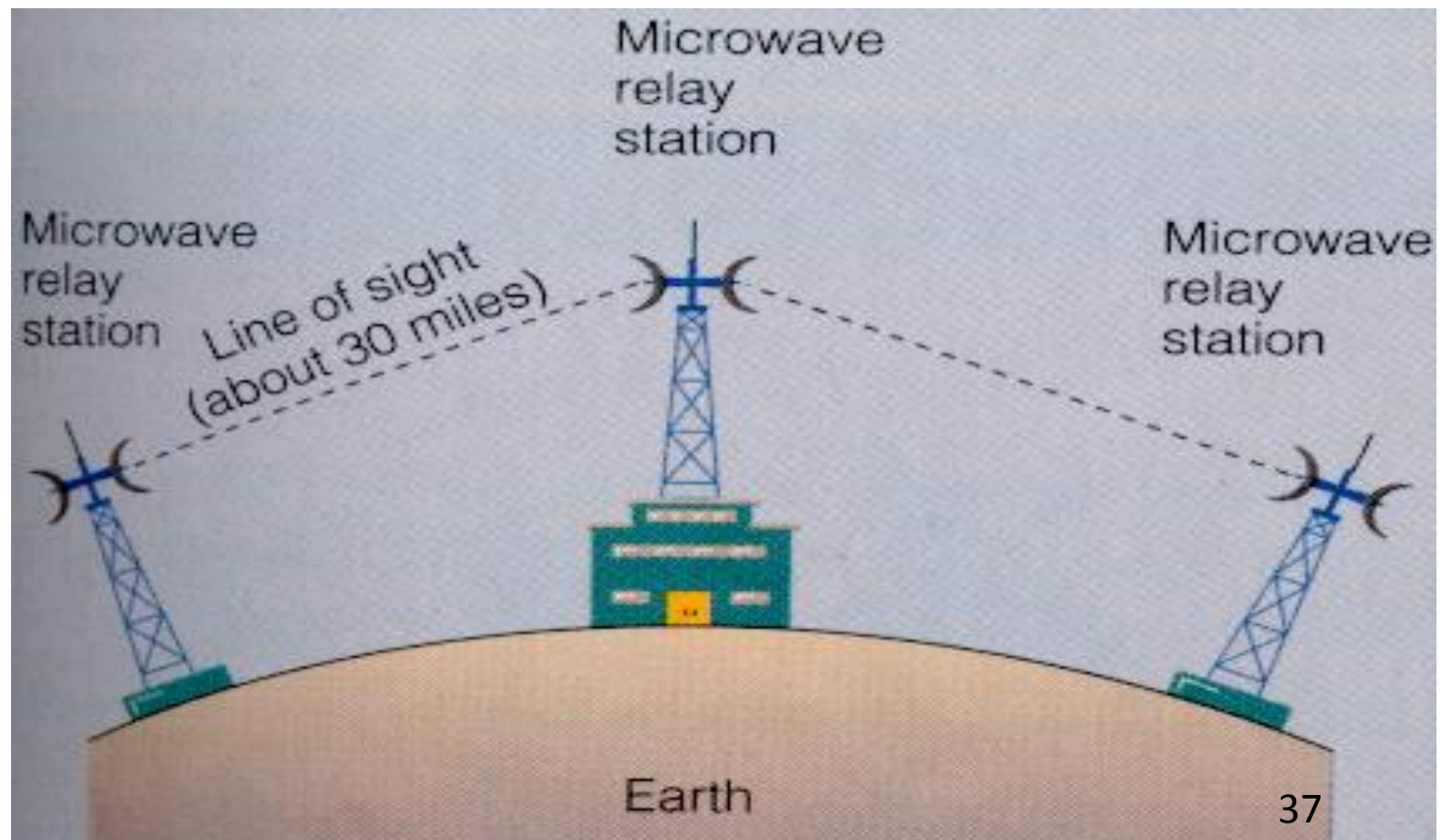


TRANSMISSION MEDIA

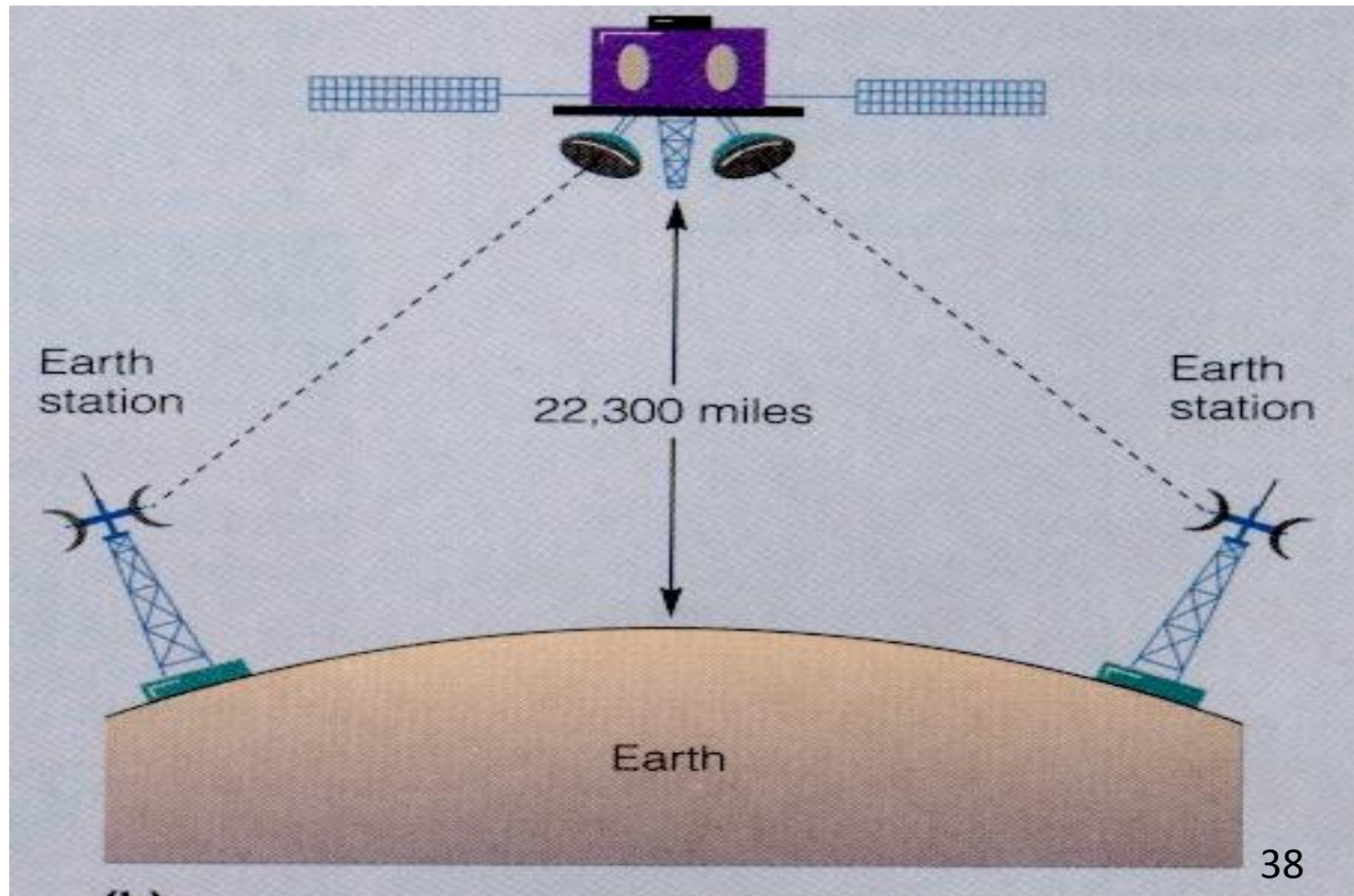
Fiber Optic Cable



TRANSMISSION MEDIA – Microwave



TRANSMISSION MEDIA – Satellite



Networks Peripherals (device)

- Network Interface Card (NIC)
- Repeater
- Hub
- Bridge
- Switch
- Router

Basic Equipment: Cards/Cables



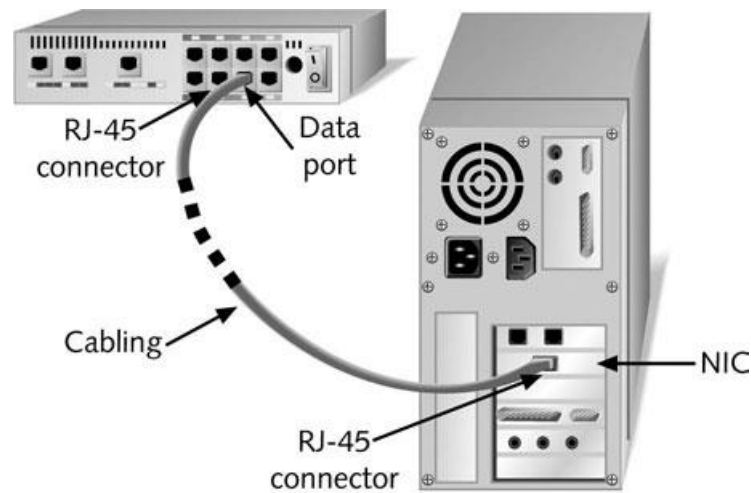
Networks Peripherals (device)

Network Interface Card (NIC)

- NIC provides the physical interface between computer and cabling.



Connecting a workstation to a switch



Networking Devices

Repeater, HUB, Switches, Routers, Wireless Access Points, Modems etc.



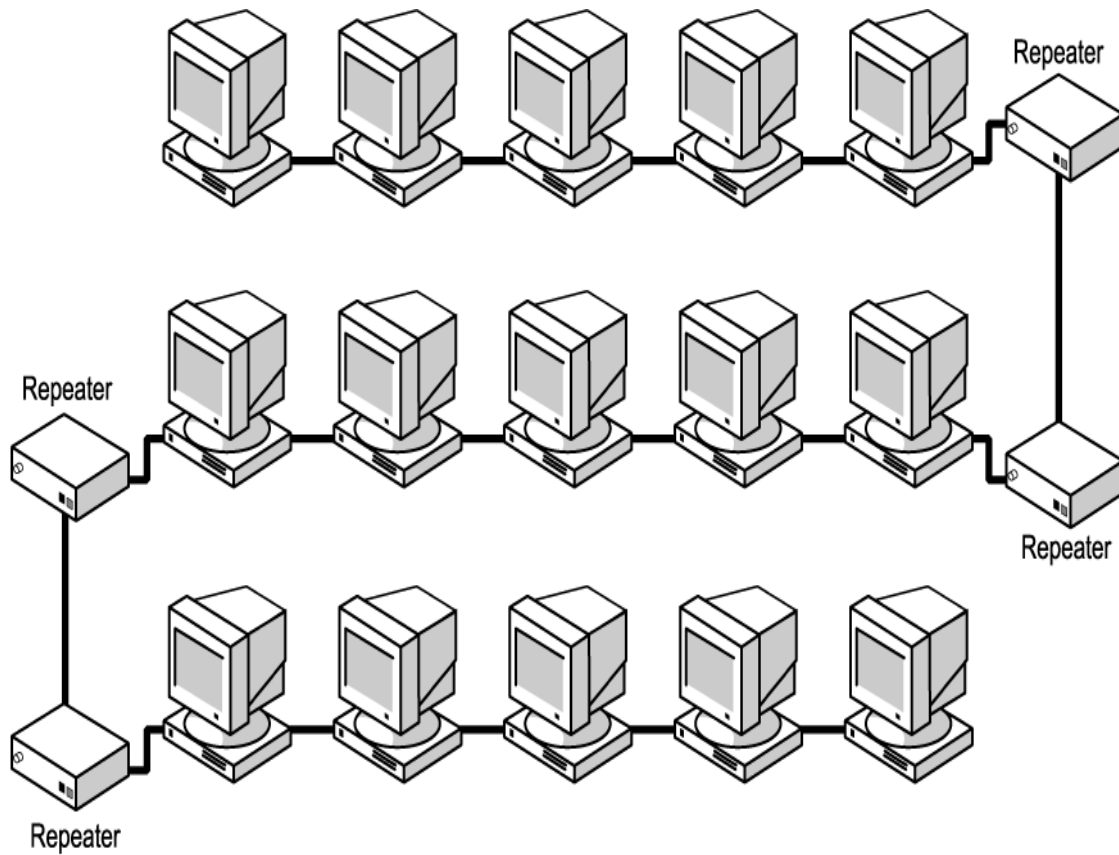
Repeater

- Contains one input port and one output port, so it is capable only of receiving and repeating a data stream
- Suited only to bus topology networks

Advantage:

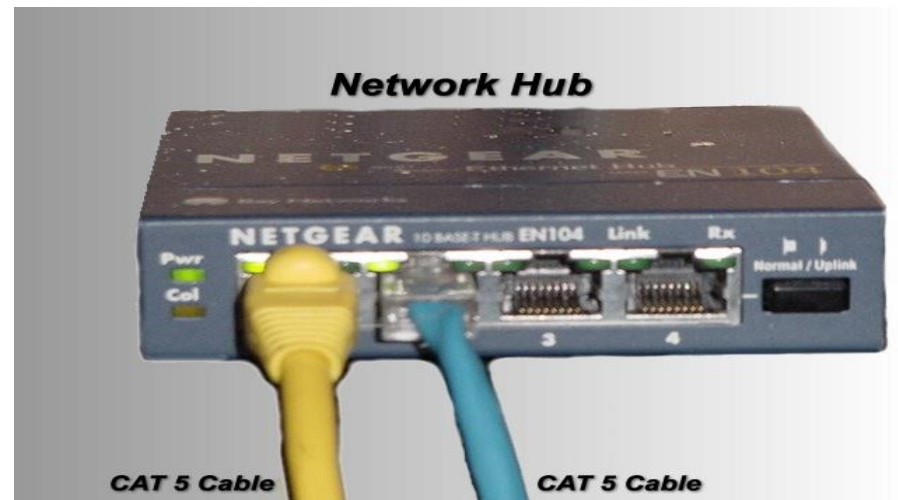
Allows you to extend a network inexpensively

Repeaters

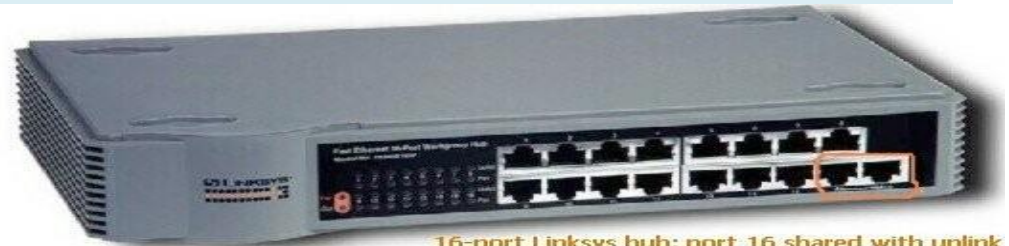
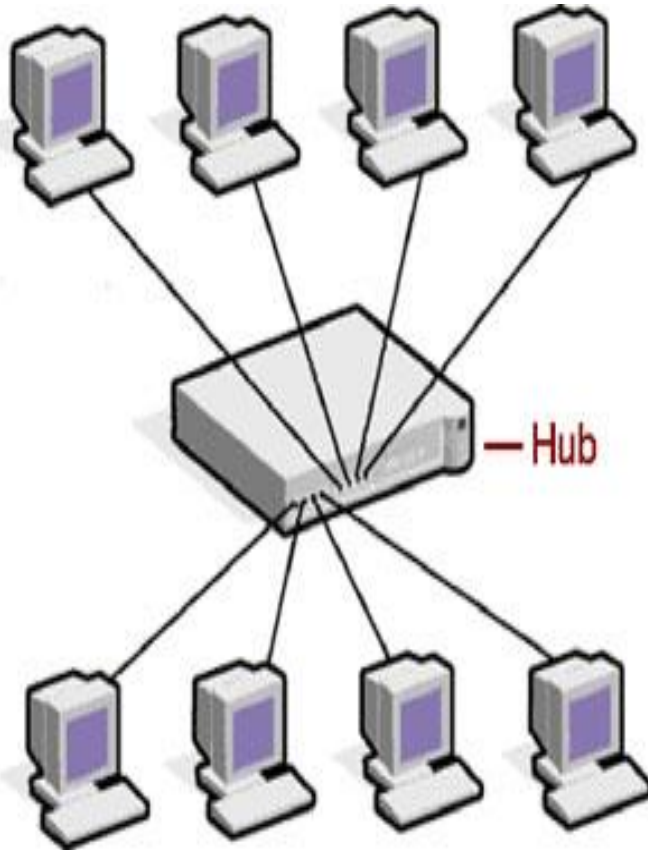


Hub

- A device that serves as the center of a star topology network.



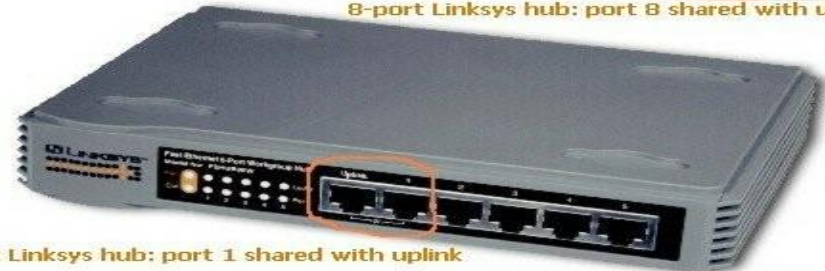
Hubs



16-port Linksys hub: port 16 shared with uplink



8-port Linksys hub: port 8 shared with uplink



5-port Linksys hub: port 1 shared with uplink



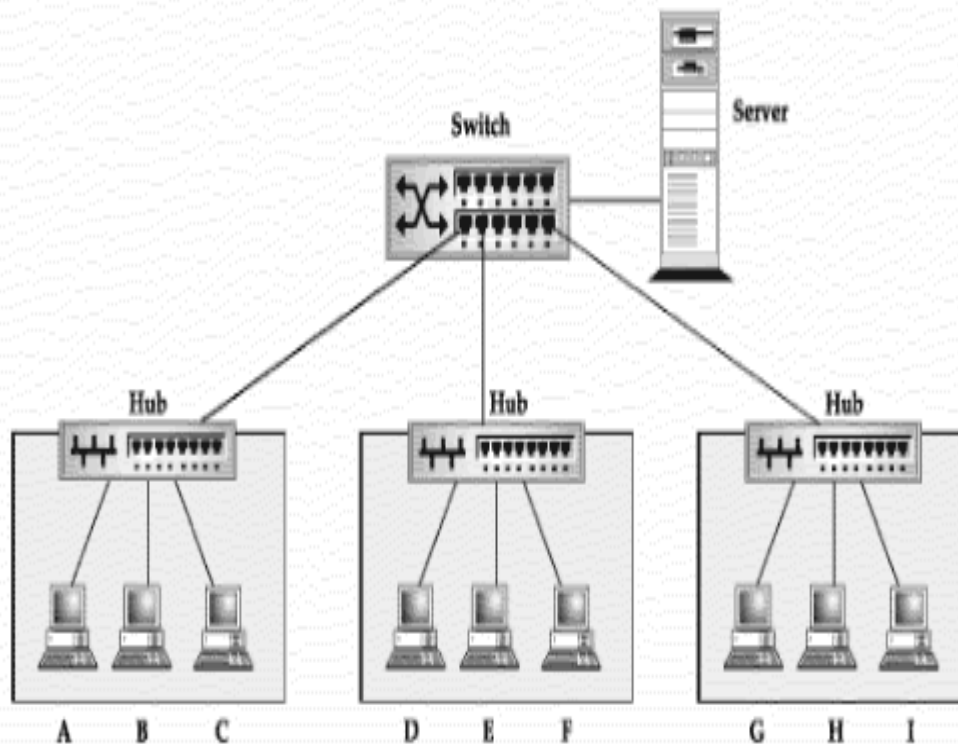
8-port SMC Hub: port 8 shared with uplink

Switch

- **Switch** : Network device that filters, forwards, and floods frames based on the destination address of each frame.
- The switch operates at the data link layer of the OSI model.



Hub & Switch



Networks Peripherals (device)

- **Routers:** *router is responsible for sending data from one network to another and is a layer-3 device.*
- used to connect the LAN to a WAN environment
- use a routing table to determine how to reach a system on a destination network.

Routers

D-Link DIR-450(EV-DO)



D-Link
Building Networks for People

D-Link DIR-451(UMTS/HSDPA)

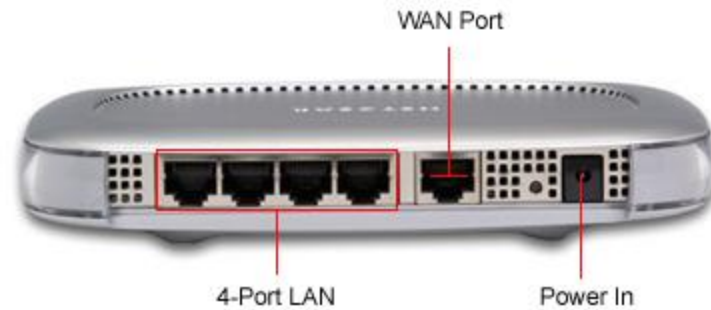
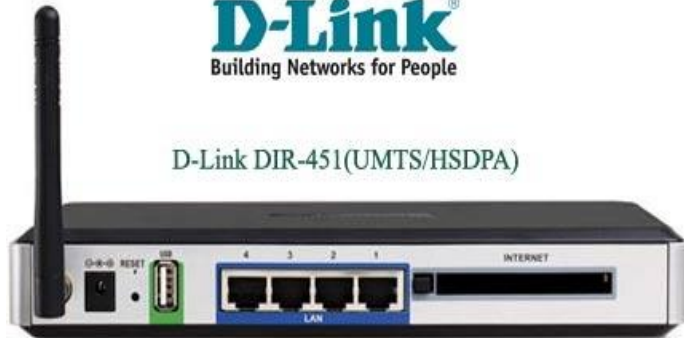
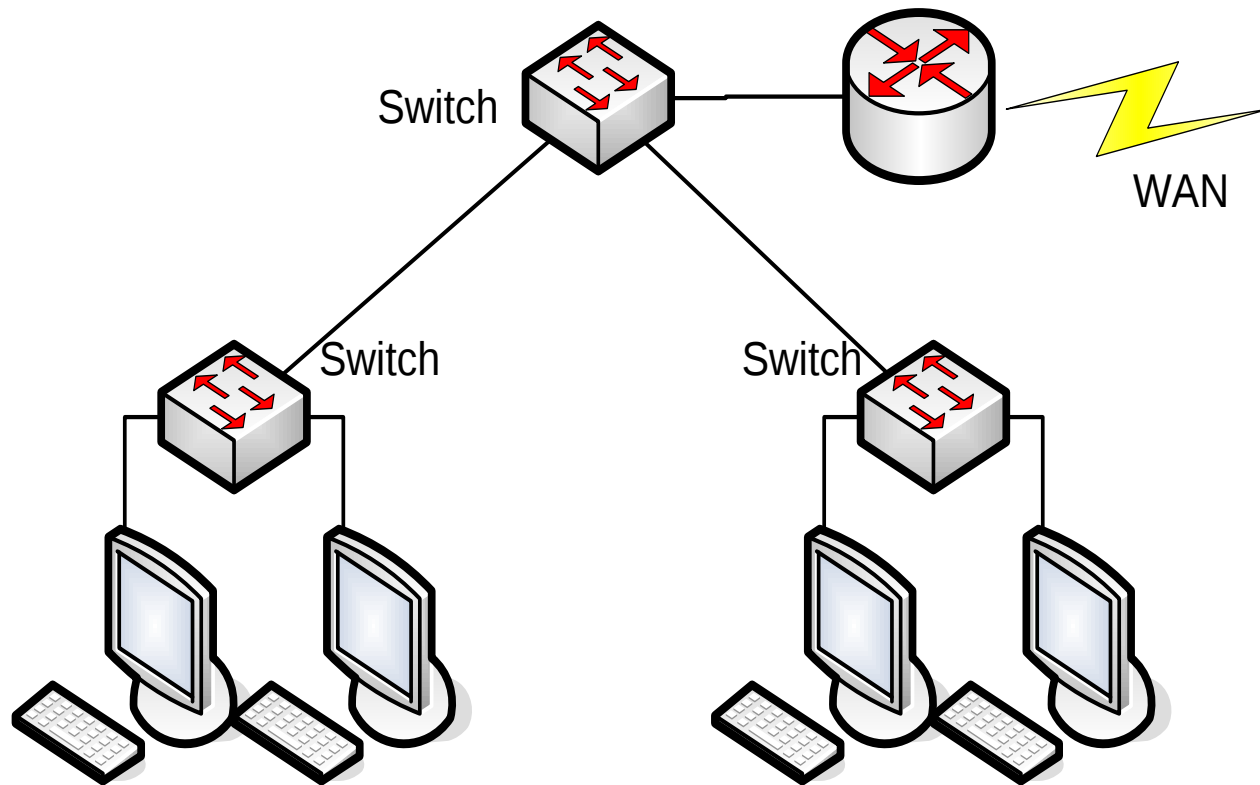


Figure: Switched networks creating an internetwork



What is an IP address

- a way to identify the machines on a network
- A unique identifier
- Every IP address consists of two parts, one identifying the **network** and one identifying the **host**

IP usage

- Used to connect to another computer
- Allows transfers of files and e-mail

IP structure

- IP addresses consist of **four sections**
- Each section is 8 bits (octets) long
- Each section can range from 0 to 255
- Uses a dot to separate octets
- Known as **dotted decimal** notation
- **5 Classes** of IP address A B C D and E
- for example, **128.35.0.72**

Dotted Decimal Notation

Bit	8	7	6	5	4	3	2	1
	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Value	128	64	32	16	8	4	2	1

10000000	10001111	10001001	10010000
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1st Byte

2nd Byte

3rd Byte

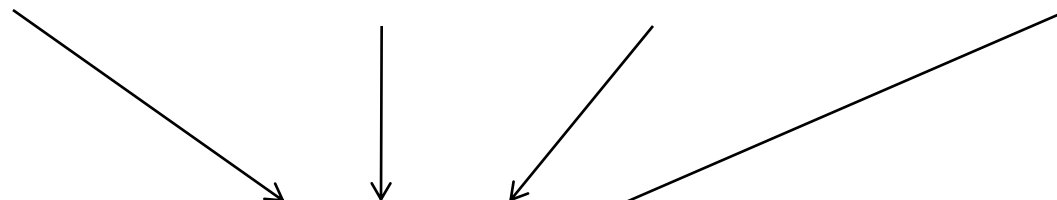
4th Byte

=128

=143

=137

=144



128.143.137.144

Dotted Decimal Notation

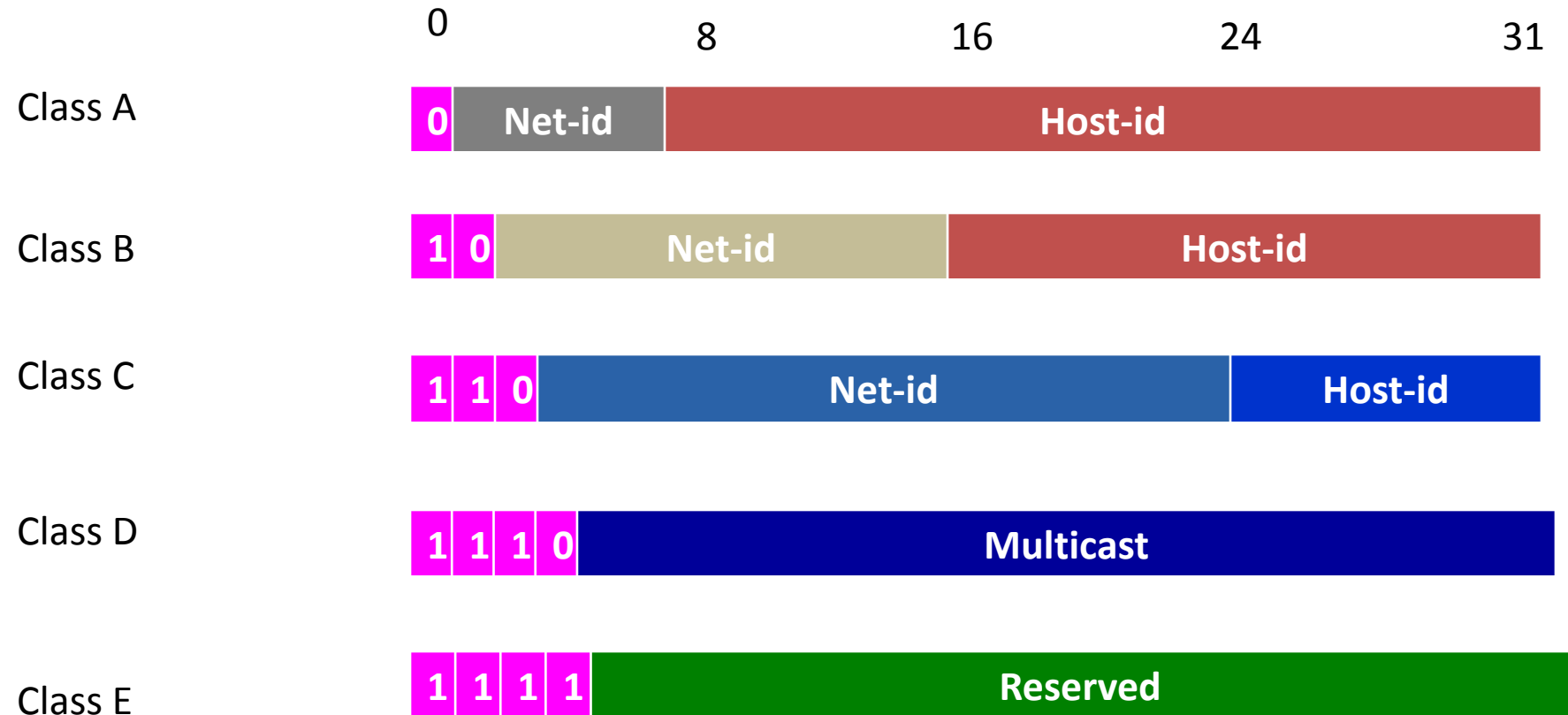
32 bit binary Number				Equivalent Dotted Decimal
10000001	00110100	00000110	00000000	129.52.6.0
11000000	00000101	00110000	00000011	192.5.48.3
00001010	00000010	00000000	00100101	10.2.0.37
10000000	00001010	00000010	00000011	128.10.2.3
10000000	10000000	11111111	00000000	128.128.255.0

Address Class

The class is recognized by the decimal value of the first octet

- Class A 1 through 126
- Class B 128 through 191
- Class C 192 through 223
- Class D 224 through 239
- Class E 240 through 255

IP Classes



IP Classes

Address Class	High-Order Bits	First Octet Address Range	Number of Bits in the Network Address	Number of Networks	Number of Hosts per Network
Class A	0	0-127	8	126	16,777,216
Class B	10	128-191	16	16,384	65,536
Class C	110	192-223	24	2,097,152	254
Class D	1110	224-239	28	N/A	N/A

Address Class

	First Octet Value	Subnet Mask	Number of Network	# of Hosts per Network
Class A	1-126	255.0.0.0	126	16,777,214
Class B	128-191	255.255.0.0	16384	65,534
Class C	192-223	255.255.255.0	2,097,152	254
Class D	224- 239	255.255.255.255	N/A	268,435,456 unique multicast
Class E	240–255		N/A	experimental purposes

IP Classes

Byte 1

Byte 2

Byte 3

Byte 4

Class A

0 Net-id

Host-id

Class B

10 Net-id

Host-id

Class C

110 Net-id

Host-id

Class D

1110 Multicast

Class E

1111 Reserved

IP Classes

From

To

Class A

0.0.0.0

Net-id

Host-id

127.255.255.255

Net-id

Host-id

Class B

128.0.0.0

Net-id

Host-id

191.255.255.255

Net-id

Host-id

Class C

192.0.0.0

Net-id

Host-id

223.255.255.255

Net-id

Host-id

Class D

224.0.0.0

Multicast address

239.255.255.255

Multicast address

Class E

240.0.0.0

Reserved

255.255.255.255

Reserved

63

Reserved addresses

- Addresses beginning 127 are reserved for loopback and internal testing
- xxx.0.0.0 reserved for network address
- xxx.255.255.255 reserved for broadcast

Special IP addresses

	Net-id	Host-id
Network address	specific	All 0's
	Net-id	Host-id
Direct Broadcast address	specific	All 1's
	Net-id and Host-id	
Loop back interface (local host)	127.0.0.0 to 127.0.0.255	

Private Address

Class	Private IP address		
Class A	10.0.0.0	–	10.255.255.255
Class B	172.16.0.0	–	172.31.255.255
Class C	192.168.0.0	–	192.168.255.255
Loopback address	127.0.0.1		

Subnet Mask

- Used to distinguish the Network ID from Host ID.

	Dot-decimal Address	Binary
Full Network Address	192.168.5.10	11000000.10101000.00000101.10000010
Subnet Mask	255.255.255.0	11111111.11111111.11111111.00000000
Network Portion	192.168.5.0	11000000.10101000.00000101.00000000
Host Portion	0.0.0.10	00000000.00000000.00000000.00001010

IP Subnet and Variable Length Subnet Masks (VLSMs)

- Subnetting: one large network break into smaller networks

Benefit of Subnetting:

- Reduced network traffic
- Optimized network performance
- Simplified management
- Facilitated spanning of large geographical distances

To Create Subnet:

- the number of required network ID.
- the number of required host IDs per subnet.

IP Classes (Classful)

0 8 16 24 31

Class A



Class B



Class C



Default Subnet Mask

Class	Format	Default Subnet Mask
A	network.node.node.node	255.0.0.0
B	network.network.node.node	255.255.0.0
C	network.network.network.node	255.255.255.0

IP Classes (Subnet)

Host bits are reassigned as network bits

0 8 16 24 31

Class A



Class B



Class C



Mask	128	192	224	240	248	252	254 /NA	255 /NA
Bits Borrowed	1	2	3	4	5	6	7	8
Value	128	64	32	16	8	4	2	1
Subnets	2	4	8	16	32	64	128	256

CIDR Subnet Mask Values

Class C subnet

Subnet Mask	Binary	CIDR Subnet Mask
255.255.255.128	11111111.11111111.11111111.10000000	/25
255.255.255.192	11111111.11111111.11111111.11000000	/26
255.255.255.224	11111111.11111111.11111111.11100000	/27
255.255.255.240	11111111.11111111.11111111.11110000	/28
255.255.255.248	11111111.11111111.11111111.11111000	/29
255.255.255.252	11111111.11111111.11111111.11111100	/30

Note: We cannot use a /31 or /32 because we have to have at least 2 host bits for assigning IP addresses to hosts.

Subnetting a Class C Address

- $2^x = \text{number of subnets}$
(x is the number of masked bits)
- $2^y - 2 = \text{number of hosts per subnet}$
(y is the number of unmasked bits, or the 0s)
- $256 - \text{subnet mask} = \text{block size}$
- Broadcast address
(the number right before the next subnet)
- Valid host addresses in each subnet
Number between the subnets omitting the all 0s and all 1s.

Class C Subnetting Example

Eg: 11000000 (/26)=192

Number of subnets= $2^2=4$

Number of hosts per subnet= $2^6-2=62$

Valid subnet=block size=256-192=64
(0,64,128,192)

The subnets (do this first)	0	64	128	192
First host	1	65	129	193
Last host	62	126	190	254
The broadcast address (do this second)	63	127	191	255

Subnet Class B Addresses

Subnet Mask	Binary	CIDR Subnet Mask
255.255.128.0	11111111.11111111.10000000.00000000	/17
255.255.192.0	11111111.11111111.11000000.00000000	/18
255.255.224.0	11111111.11111111.11100000.00000000	/19
255.255.240.0	11111111.11111111.11110000.00000000	/20
255.255.248.0	11111111.11111111.11111000.00000000	/21
255.255.252.0	11111111.11111111.11111100.00000000	/22
255.255.254.0	11111111.11111111.11111110.00000000	/23
255.255.255.0	11111111.11111111.11111111.00000000	/24
255.255.255.128	11111111.11111111.11111111.10000000	/25
255.255.255.192	11111111.11111111.11111111.11000000	/26
255.255.255.224	11111111.11111111.11111111.11100000	/27
255.255.255.240	11111111.11111111.11111111.11110000	/28
255.255.255.248	11111111.11111111.11111111.11111000	/29
255.255.255.252	11111111.11111111.11111111.11111100	/30

Subnet Class A Addresses

Subnet Mask	Binary	CIDR Subnet Mask
255.128.0.0	11111111.10000000.00000000.00000000	/9
255.192.0.0	11111111.11000000.00000000.00000000	/10
255.224.0.0	11111111.11100000.00000000.00000000	/11
255.240.0.0	11111111.11110000.00000000.00000000	/12
255.248.0.0	11111111.11111000.00000000.00000000	/13
255.252.0.0	11111111.11111100.00000000.00000000	/14
255.254.0.0	11111111.11111110.00000000.00000000	/15
255.255.0.0	11111111.11111111.00000000.00000000	/16

Subnet Class A Addresses(cont'd.)

Subnet Mask	Binary	CIDR Subnet Mask
255.255.128.0	11111111.11111111.10000000.00000000	/17
255.255.192.0	11111111.11111111.11000000.00000000	/18
255.255.224.0	11111111.11111111.11100000.00000000	/19
255.255.240.0	11111111.11111111.11110000.00000000	/20
255.255.248.0	11111111.11111111.11111000.00000000	/21
255.255.252.0	11111111.11111111.11111100.00000000	/22
255.255.254.0	11111111.11111111.11111110.00000000	/23
255.255.255.0	11111111.11111111.11111111.00000000	/24
255.255.255.128	11111111.11111111.11111111.10000000	/25
255.255.255.192	11111111.11111111.11111111.11000000	/26
255.255.255.224	11111111.11111111.11111111.11100000	/27
255.255.255.240	11111111.11111111.11111111.11110000	/28
255.255.255.248	11111111.11111111.11111111.11111000	/29
255.255.255.252	11111111.11111111.11111111.11111100	/30

Variable Length Subnet Masks (VLSMs)

- Classful routing protocols: RIP1, IGRP (no subnet information)
- Classless routing protocols: RIP2, EIGRP, OSPF (subnet information)

Benefit of VLSM:

- summarization
- save bandwidth

Addressing Scheme

- Unicast (one to one)
- Multicast (one to many)
- Broadcast (all)

OS Utilities

- TRACERT
- IPCONFIG
- PING
- NSLOOKUP
- ARP -A

ANY QUESTIONS OR ADDITIONS?

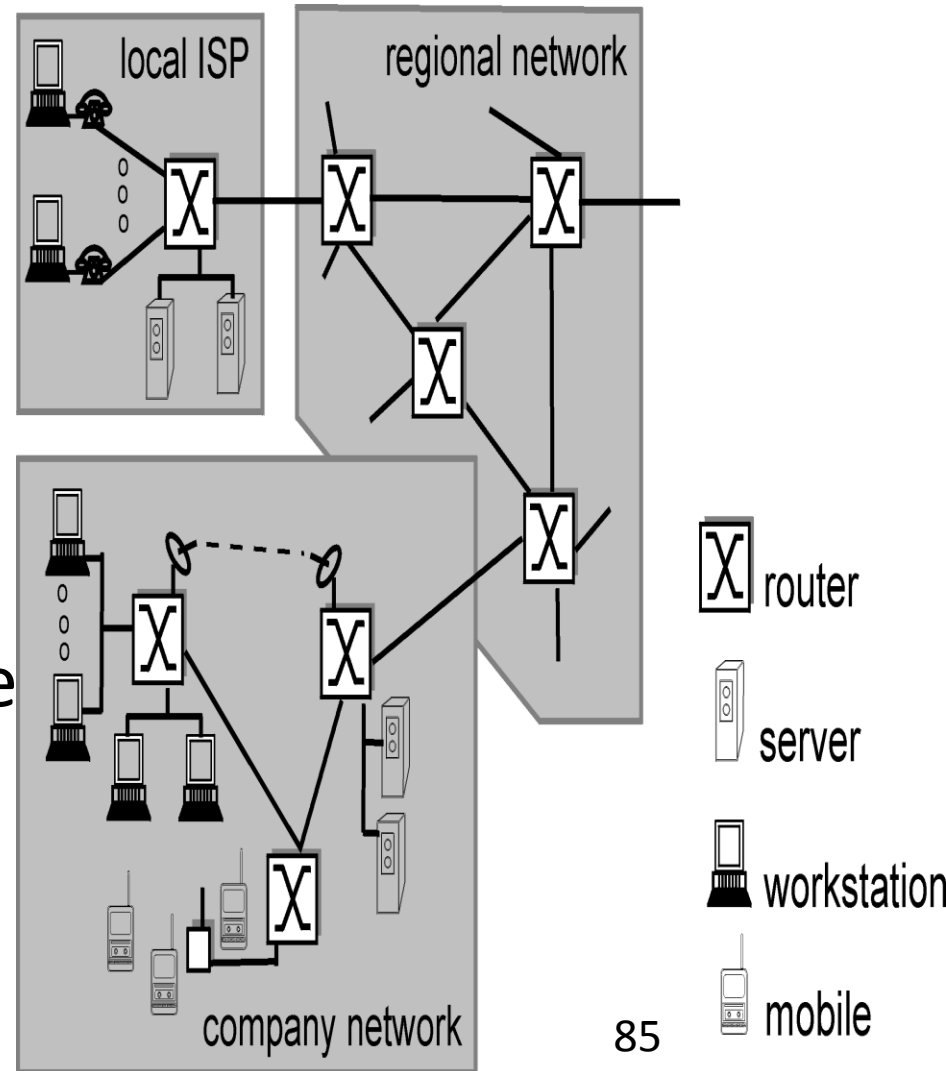
Internet Architecture

Roadmap

- What is the Internet?
- Network edge
- Network core
- Protocol layers, service models

What's the Internet

- millions of connected computing devices: **hosts, end-systems**
 - PCs workstations, servers
 - PDAs phones, toasters running **network apps**
- **communication links**
 - fiber, copper, radio, satellite
 - transmission rate = **Bandwidth (~ bps)**
- routers: forward packets (chunks of data)



What's the Internet (cont'd)

- **protocols** control sending, receiving of msgs
e.g., TCP, IP, HTTP, FTP, PPP
- **Internet: “network of networks”**
 - loosely hierarchical
 - public Internet versus private intranet
- Internet standards
 - RFC: Request for comments
 - IETF: Internet Engineering Task Force

A closer look at network structure:

- network edge:
 - applications and hosts
- network core:
 - Routers
 - network of networks
- access networks, physical media:
 - communication links

Network edge:

connection-oriented service

- Goal: data transfer between end systems
 - handshaking: setup (prepare for) data transfer ahead of time
 - Hello, hello back human Protocol
 - **set up “state”** in two communicating hosts
 - TCP - Transmission Control Protocol
 - Internet’s connection-oriented service
- TCP service [RFC 793]
 - reliable, in-order byte-stream data transfer
 - loss: acknowledgements and retransmissions
 - **flow control**:
 - sender won’t overwhelm receiver
 - **congestion control**:
 - senders “slow down sending rate” when network congested

Figure : Establishing a connection-oriented session

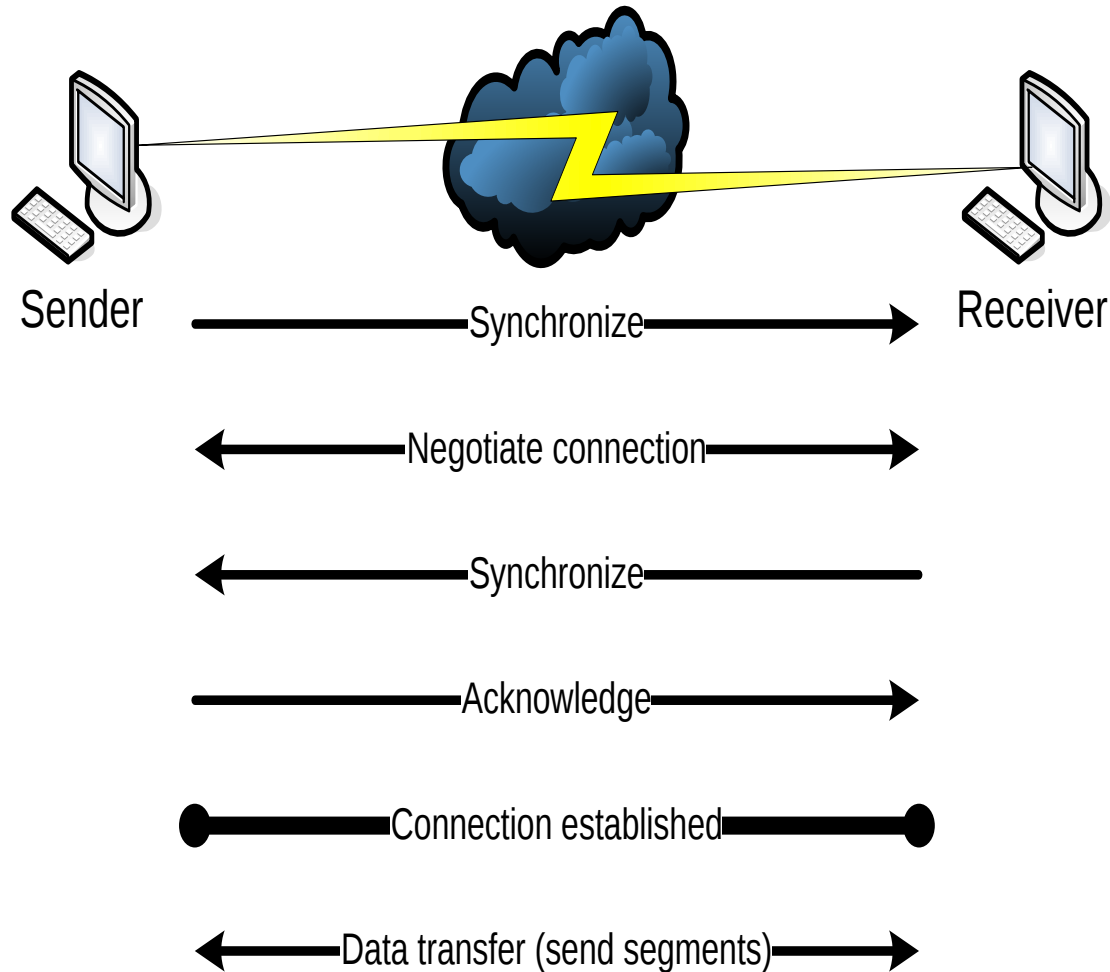
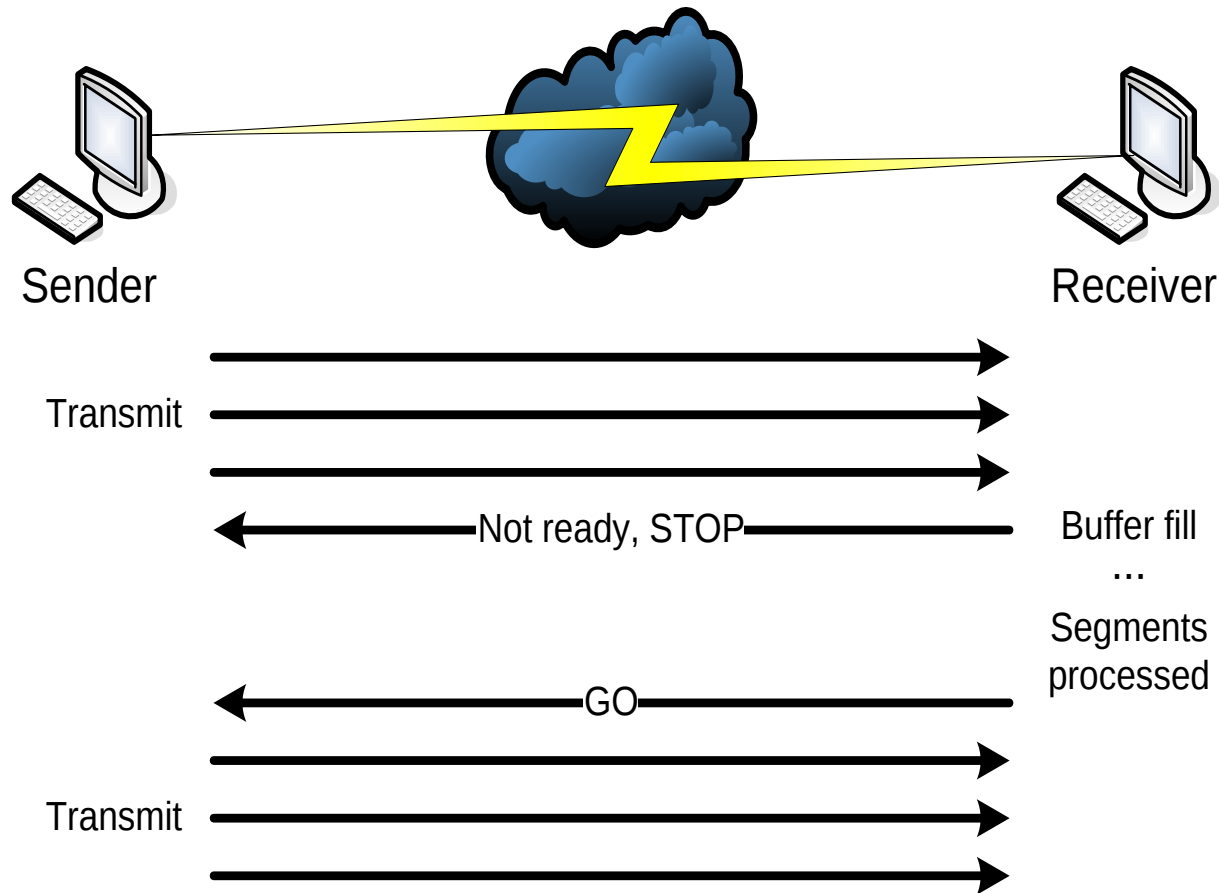


Figure :Transmitting segments with flow control



Network edge: connectionless service

- Goal: data transfer between end systems same as before!
- **UDP** - User Datagram Protocol [RFC 768]:
Internet's connectionless service
- unreliable data transfer
- no flow control
- no congestion control

App's using TCP:

- HTTP (Web), FTP (file transfer), Telnet (remote login), SMTP (email)

App's using UDP:

- streaming media, teleconferencing, DNS, Internet telephony

The Network Core

- mesh of interconnected routers
- the fundamental question: how is data transferred through net?
- **circuit switching**: dedicated circuit per call: telephone net
- **packet-switching**: data sent through net in discrete “chunks”

Network Core: Circuit Switching

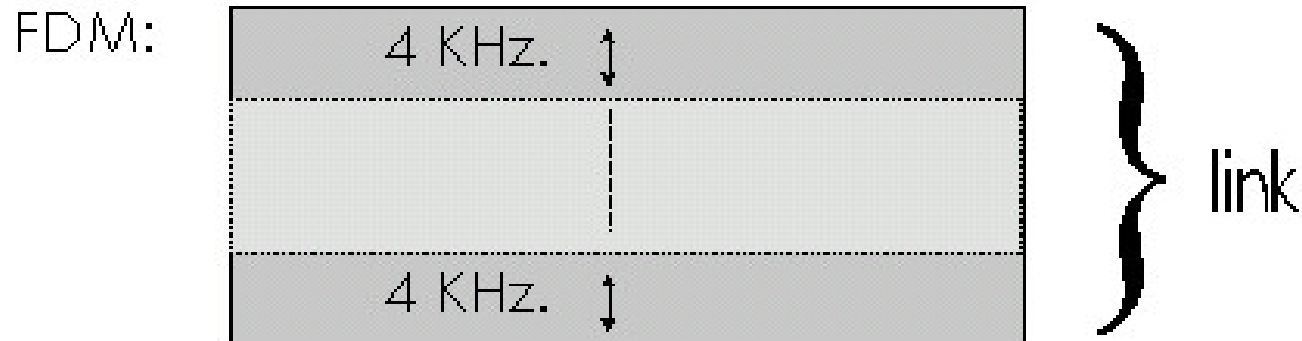
End-end resources reserved for “call”

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required

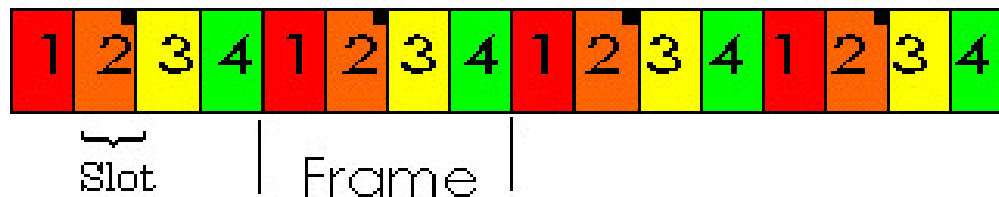
Network Core: Circuit Switching

- network resources
- (e.g., bandwidth)
- **divided into “pieces”**
 - pieces allocated to calls
 - resource piece **idle** if not used by owning call (no sharing)
 - dividing link bandwidth
- into “pieces”
- frequency division
- time division

Circuit Switching: FDMA and TDMA



TDM:



All slots labelled  are dedicated to a specific sender-receiver pair.

Network Core: Packet Switching

each end-end data stream

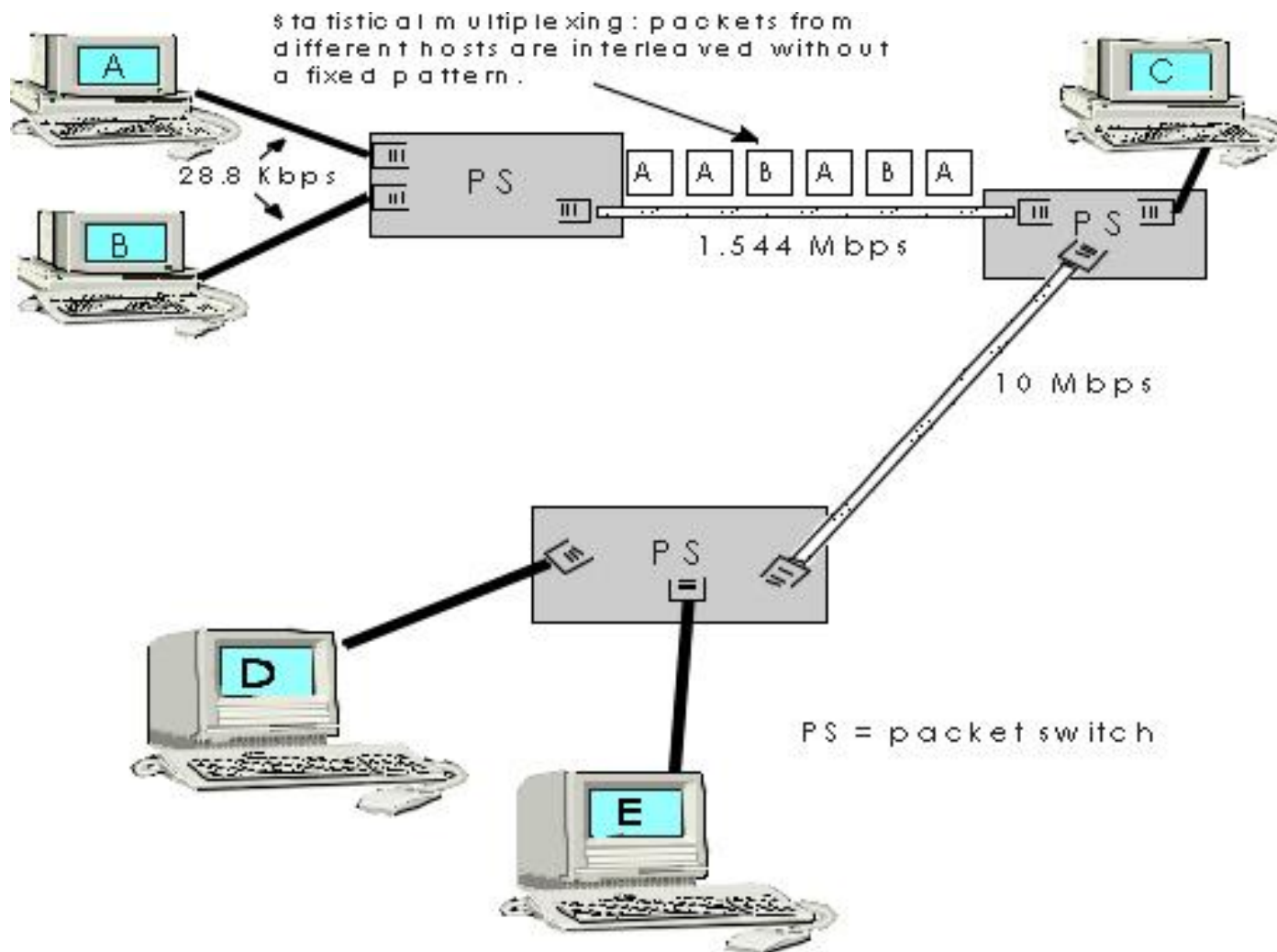
divided into packets

- user A, B packets share network resources
- each packet uses full link bandwidth
- resources used as needed
- xxxxxxxxxxxxxxxx
- Bandwidth division into “pieces”
- Dedicated allocation
- Resource reservation

resource contention:

- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
- transmit over link
- wait turn at next link

Packet Switching: Statistical Multiplexing



Packet switching versus circuit switching

- Packet switching allows more users to use network!
- 1 Mbit link
- each user:
 - 100 kbps when “active”
 - active 10% of time
- circuit-switching:
 - 10 users
- packet switching:
 - with 35 users, probability > 10 active less than .0004

Packet switching versus circuit switching

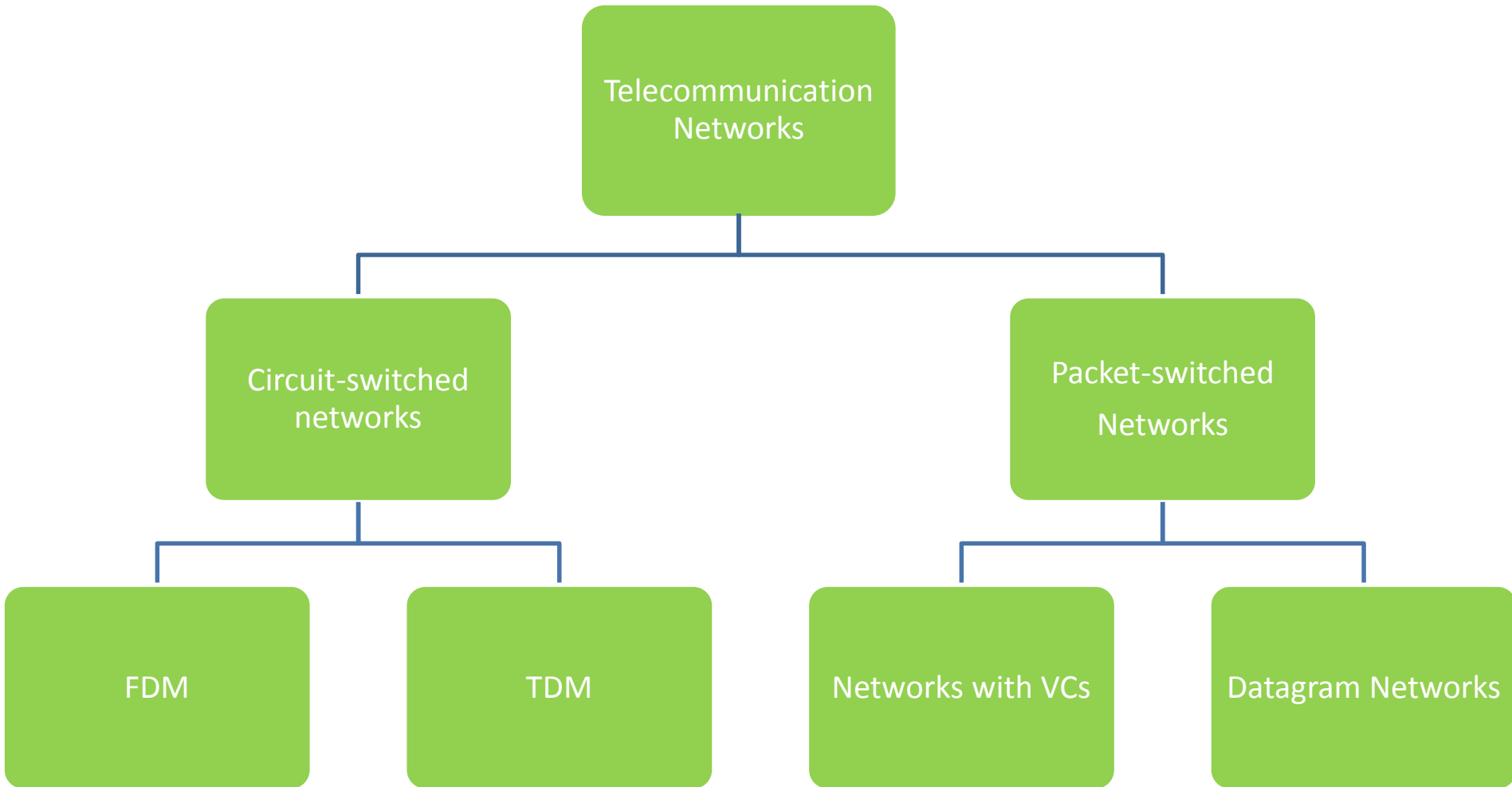
Is packet switching a “slam dunk winner?”

- Great for bursty data
 - resource sharing
 - simpler, no call setup
- **Excessive congestion:** packet delay and loss
 - protocols needed for reliable data transfer,
 - congestion control
- **Q: How to provide circuit-like behavior?**
 - bandwidth guarantees needed for audio/video apps
 - still an unsolved problem

Packet-switched networks: forwarding

- Goal: move packets through routers from source to destination
- **datagram network:**
 - destination address in packet determines next hop
 - routes may change during session
 - analogy: driving, asking directions
- **virtual circuit network:**
 - each packet carries tag (virtual circuit ID), tag determines next hop
 - fixed path determined at call setup time, remains fixed thru call
 - **routers maintain per-call state**

Network Taxonomy



Network Taxonomy

- Datagram network is not either connection-oriented or connectionless.
- Internet provides both connection-oriented (TCP) and connectionless services (UDP) to apps.

LAN PROTOCOLS

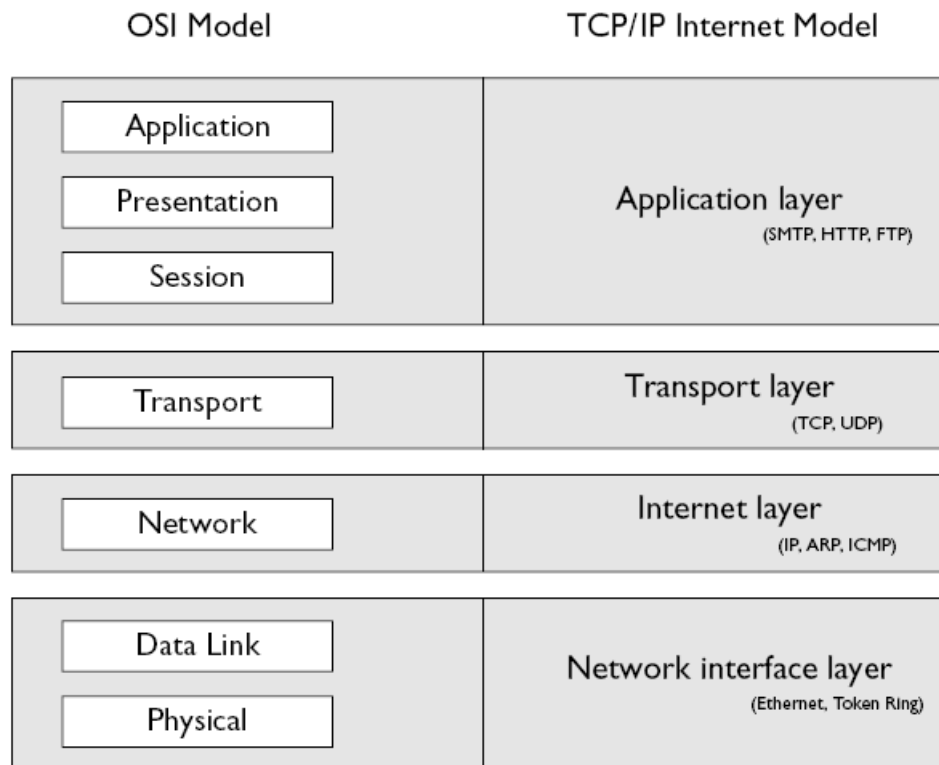
Protocol : A set of rules to access the network to send data.

Two common LAN protocols

Ethernet

Token Ring

Reference Models



Function of OSI Layers

Layer	Functionality
Application	Network service, authentication
Presentation	Translation, encryption
Session	Connection, session
Transport	Fragmentation, defragmentation, reliable data delivery, error correction, management, flow control
Network	Addressing, routing
Data Link	Packet/frame, CRC generation/checking, network access
Physical	Media, Connectors, electrical signal

Ports Used by Popular Internet Applications

Port number	Process	Description
21	FTP	File Transfer Protocol
22	SSH	Secure shell
23	TELNET	Telnet
25	SMTP	Simple Mail Transfer Protocol
110	POP3	Post Office Protocol, version -3
53	DNS	Domain Name System
80	HTTP	Hyper Text Transfer Protocol
443	HTTPS	Secure Hyper Text Transfer Protocol

Internet protocol stack

- **application:** supporting network applications
 - FTP, SMTP, STTP
- **transport:** host-host data transfer
 - TCP, UDP
- **network:** routing of datagrams from source to destination
 - IP, routing protocols
- **link:** data transfer between neighboring network elements
 - PPP, Ethernet
- **physical:** bits “on the wire”

application

transport

network

link

physical

Layering: logical communication

- Each layer:
- ☐ distributed
- ☐ “entities”
- implement
- layer functions
- at each node
- ☐ entities
- perform
- actions,
- exchange
- messages with peers

Layering: logical communication

- E.g.: transport
- ☐ take data from app
- ☐ add addressing,
- reliability check
- info to form
- “datagram”
- ☐ send datagram to
- peer
- ☐ wait for peer to
- ack receipt
- ☐ analogy: post office

Layering: physical communication

Protocol layering and data

- Each layer takes data from above
- [?] adds header information to create new data unit
- [?] passes new data unit to layer below

- **Internet Architecture**
- You know what the following
- terms mean: router, switches, ISP,
- AS.
- You know how Internet is different
- from a Telephony network.

- **Protocol Layers**
- You know the functionalities of 5
- layers of the Internet protocol
- stack.

- **Naming/Addressing**
- You know what is a domain name,
- what is an IP address, and how to
- map between the two.
- You know how DHCP assigns a
- dynamic IP address to you host.

- **Application Protocol**
- You roughly know how HTTP and
- FTP works.

- **Transport Protocol**
- You know what is a port and
- socket
- You can tell the differences
- between TCP and UDP. You know
- in what situation you should use which.

- **TCP**
- You know why congestion control
- and flow control are needed. You
- roughly know how TCP's
- congestion control works.

- **Network Layer**
- You know that almost everything
- runs on IP. You know how
- packets are routed on the Internet,
- at least within an AS.

- **Network Layer**
- You know what's a private IP
- address and why NAT makes P2P file sharing difficult.

- **Ethernet**
- You know why Ethernet is a
- random access protocol. You
- know what collision and backoff
- mean in this context.

- **Ethernet**

- You know why MAC address is
- needed despite having an IP
- address.
- You know how mapping between
- MAC and IP addresses is done.

- **Tools**
- You have used ping or traceroute.
- Or at least heard about them and
- know what they are for.

- **Basic Probability**
- You know what is expected value,
- variance, random variable, and
- cumulative distribution function.
- You know how to compute
- conditional probability and
- probability of two events.

- **Programming**
- You know how to program in C or
- C++, and is comfortable in picking
- up new languages.

Review Questions

1. The principle characteristic of connection-oriented and connectionless